AN ATTEMPTED TEST OF ANDERSON'S CLAIM THAT THERE CAN BE NO DETERMINANT TEST DIFFERENTIATING THEORIES OF MENTAL IMAGERY

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ABSTRACT

An experiment was designed to test Anderson's claim for a fundamental indeterminacy between evidence for the nature of a mental images' representation and evidence for the nature of imagery processing. Imagery representation was investigated with Attneave Polygon stimuli operationalizing Hochberg and Gellman's concept of landmark feature saliency. Imagery processing was approached with a combination of Sternberg's memory search paradigm and Shepard and Cooper's mental rotation paradigm. Between one and four stimuli were memorized with the duration of memorization being under subject control. This was followed by presentation of a single misoriented test stimulus and recording of the time and correctness of discriminative responses. The test stimulus was either a match of a memory set stimulus ('same' response), a mirror image of a memory set stimulus ('different' response) or a stimulus which had not occurred in the memory set on that trial ('different' response). High and low imagery subjects, chosen on the basis of extreme scores on Marks' Vividness of Visual Imagery Questionnaire, were both included in the task to allow comparison of the functional importance of imagery ability at different processing stages. Contrary to expectations no difference was found between imagery groups and no systematic differences distinguished stimuli. These results made conclusions about the nature of imagery representation impossible and caused the utility of the

concept 'landmark feature saliency' to be questioned. High error rates also occurred. However, in replication of previous research findings, a rotational transformation stage was found after an initial stimulus identification stage based on rotationally invariant features. Tentative evidence was found for a recoding stage after stimulus identification and a time-limited strategy appeared to operate in the detection of mirror image test stimuli. A modified procedure is suggested to further test Anderson's indeterminacy claim.

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Much thanks is also due to my mother Pauline and my wife Judith who have both in their turn supported, encouraged and chastised me until this thesis was finally completed.

Mention must also be made of several serendipitious discoveries made during the course of the experiment:

(1) Murphies Law is an excellent excuse for lack of foresight.

(2) Even pessimism, when faced with a deadline, is optimistic.

(3) Being a parasite on somebody else's computer system is the ideal.

(4) Getting married takes some time, but being married requires even longer.

CONTENTS

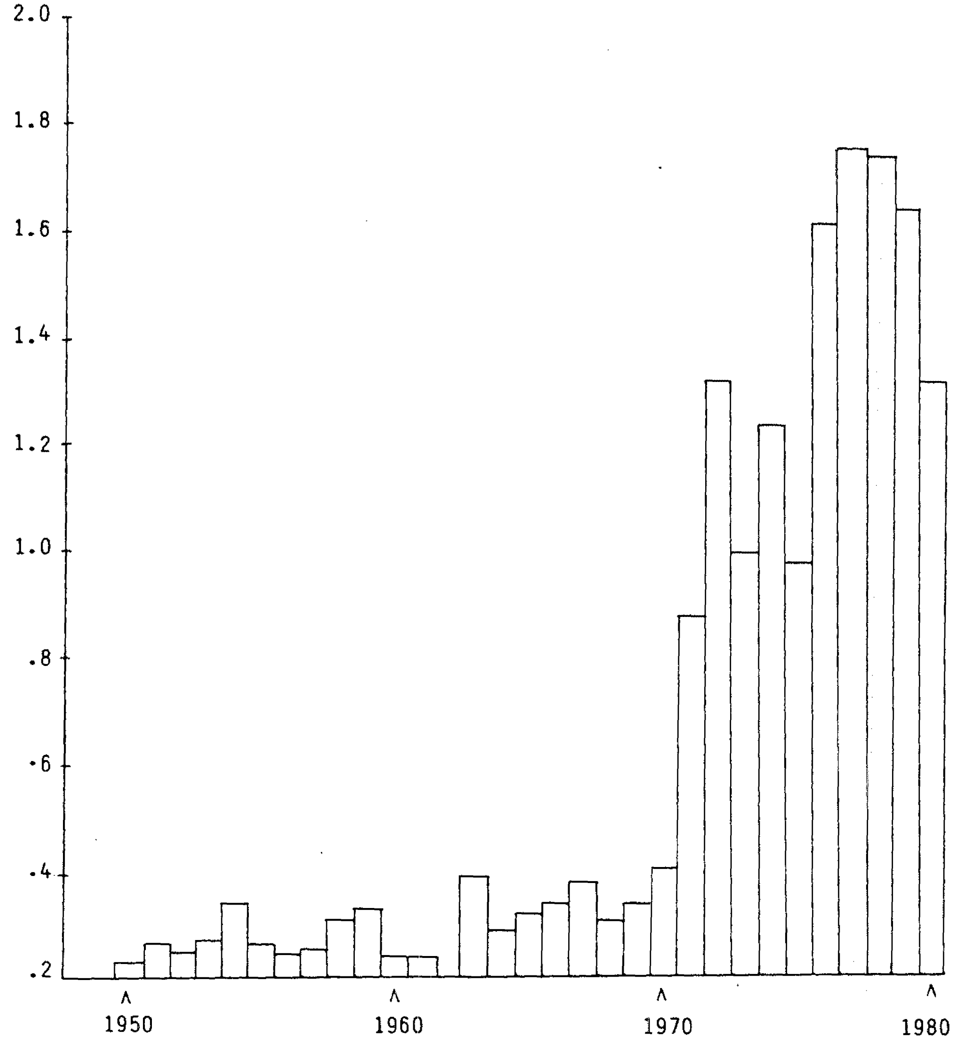
CHAPTER I

INTRODUCTION

AN HISTORICAL REVIEW OF IMAGERY RESEARCH SHOWING THE UNIQUE CONTRIBUTION OF 'MENTAL ROTATION' EXPERIMENTS

Speculation on the mental processes involved in an object recognition task using rotated figures, dates back at least to Ernst Mach in 1886. He noted that "...when, however, we turn one spot far enough round with respect to the other..., their identity of form is not recognizable without intellectual assistance... the affinity of form is recognizable only by turning the figure around or by an intellectual act". (Mach, 1886, p107). Although alterations in phenomenal shape with rotation were extensively investigated up to the 1970's (as reviewed by Rock, 1973), the investigation of the actual processes involved within the "intellectual act" lay dormant until the publishing of Shepard and Metzler's 1971 Science article, "Mental Rotation of Three Dimensional Objects". (M. Arnoult 1954 published an experiment of the same design but totally failed to speculate on the processes involved in shape discrimination being more concerned with the problem of specifying stimulus qualities). However Shepard's work came at a time of a new emphasis on mental images in experimental psychology. (See figure 1). Mental imagery has been described (Paivio 1975, Neisser 1972) as acting, in Kuhnian terms, as one of the anomalies which gives rise to a Scientific Revolution. The role of the mental rotation anomaly in cognitive psychology could be described in the following manner: "Produced inadvertently by a game played

FIGURE 1



Bar graph showing articles indexed under the heading 'imagery' in Psychological Abstracts as a percentage of total articles abstracted in a year. (No data is available for 1962 due to idiosyncracies of the referencing method used experimentally that year).

under one set of rules, their assimilation requires the elaboration of another set. After they have become parts of science, the enterprise, at least of those specialists in whose particular field the novelties lie, is never quite the same again". (Kuhn, 1970, p52). To understand precisely the extraordinary nature of the series of mental rotation experiments, conducted mainly by Shepard and his co-workers, it is necessary to understand the history of imagery research.

Imagery was vigorously investigated by the early psychologists, notably Titchener and Galton, who used the technique of introspection. However the discovery of "imageless thought" by Kulpe's students at Wurzburg in 1901-1905 (reviewed in Boring, 1953) was seen to undermine both theorizing on the primacy of imagery in thought and the use of the introspective method to study higher mental processes (which becomes problematic if consciousness is not involved in them).

J. B. Watson strongly attacked mental imagery when he launched the Behaviourist school with his essay "Psychology as the Behaviourist views it" in 1913. After reviewing extensive studies by Angell (1910) and Fernald (1912) he found imagery to be of negligible functional significance in thinking and concluded that even the concept of an image was untenable, being linked to an "enormous structure" of theoretical ideas of questionable validity. His solution to the inadequacy of the introspective method, as highlighted in imagery studies, was to redefine Psychology as the study of behaviour and concentrate on overt responses: this rapidly became the dominant trend in Psychology.

The empirical methods for studying thinking and memory initiated by Ebbinghaus can also be seen as contributing to the eclipse of imagery, as they put an emphasis on using verbal materials and skills. (Ebbinghaus, 1885). This survived under Behaviourism as the field of Verbal Learning, with 'verbal report' being an acceptable behavioural measure (Respectable Introspection!?). Imagery however was left unstudied because it fell outside the dominant tradition of scientific practice.

The recent increase in imagery studies coincides with major changes in social values. For example, it is interesting to note that in 1964, when arguing for the reintroduction of the study of imagery, Holt could complain that, "In a functionally oriented, sceptical, anti-intraceptive brass-tack culture like ours, where the paranormal is scoffed at and myth and religion are in decline, the capacity for vivid imagery has little survival value and less social acceptability". (Holt, 1964, p262). However when he reviewed the growing field in 1972, Holt wrote that "...the resurgence of interest in imagery is part of a larger movement, in science and popular culture alike: a revival of interest in subjective, conscious phenomena". (Holt, 1972, p4).

Experimental Psychology has reflected, and in part generated, this changed outlook with its adoption of a new approach to science, described as 'neo-mentalistic'. (Paivio, 1975). It has sought to provide new objective or behavioural methods for the study of a redefined field of interest: Mind. This Cognitive Psychology was a reaction against the failure of Behaviourism to consider human mental experience, of which imagery is a prototypical phenomena. It is possible to trace the contribution of many antecedents to Cognitive Psychology such as Neo-Behaviourism, Verbal Learning, Human Engineering, Communication Engineering, Computer Science, Linguistics, and Gestalt Psychology. (Reviewed Lachman, Lachman & Butterfield, 1979). The strongest influence, however, was the metaphoric and philosophic possibilities opened up by postwar computer technology. For example it stimulated the pre-theoretic idea that Mind could be conceived as acting as a general symbol-manipulating system or Information Processor. This lead to the focus of study on the question 'what is the nature of the internal symbols or codes or representations manipulated and processed in thought?'. Early work continued the Ebbinghaus tradition and used verbal materials to examine the structure of 'semantic memory'. However when interest increased in the phenomena of mental imagery it became obvious that images might be represented in internal codes very different from language. This is illustrated in Pinker 1981, where in reviewing his own work on spatial representation and language acquisition, he concludes that they have "...little in common of any interest." (Pinker, 1981, p247). Thus imagery became a study area able to reveal important new information about the mind.

In this context the 'mental rotation experiments' importance is that they are claimed to establish an isomorphism between mental representations and observable events, proving the existence of a new type of mental code; an analog representation or 'mental sketch pad'. (Cooper & Shepard 1973; Metzler & Shepard 1974; Shepard 1975; Cooper & Shepard 1976; Shepard & Podgorny 1978; Shepard & Cooper 1980). What is more, the evidence for this is relatively direct, compared with other types of imagery research, because the data gathered concerns the timing of mental events rather than the inference of mental structures from the measurement of other variables. Other operational procedures have been to manipulate either: (1) stimulus characteristics (mainly imagery evoking ability) or (2) individual differences between subjects (groups being differentiated by either self-rating or performance on spatial tests) or (3) experimental manipulations (mainly comparing instructions to use imagery with other strategies). (Paivio, 1975; Richardson, 1980). The logic behind these procedures is that they affect the availability or accessibility of the imagery system in a given task and thus allow conclusions to be drawn regarding the functions of imagery. In contrast to studies of the associative function of imagery, which seem to require long term memory, the rotation experiments provide information on the processes involved in imagery operations in real time.

ANALOG - PROPOSITIONAL DEBACLE

Reflecting on the historical niche of mental rotation experiments in imagery research, consideration must be given to an elaborate accompanying debate on the explanatory status of imagery theories and the specific nature of the mental image. J. R. Anderson (Anderson, 1978) focused the debate by arguing that it was fundamentally impossible to distinguish between the opposing pictorial and propositional theories of the internal representation of the image. Indeterminacy exists because representation cannot be discussed in isolation but rather consideration must be given to the interplay and trade-off between representation of information and processing of that information: representation process pairs! This allows a vast range of both kinds of theories to mimic each other (with subtle parameter changes) and to produce identical behavioural predictions.

Discarding the possibility of one "true" theory, Anderson initiated an evaluation of non-behavioural constraints on theory. Specifically he considered parsimony, plausibility, efficiency, and optimality as possibly providing "ground rules" for acceptance of a theory type. Others have extended this evaluation to cover: attacks and defences of the logic of the indeterminacy argument (Hayes-Roth, 1979; Pylyshyn, 1979; Anderson, 1979); optimality and efficiency (Wilton, 1978): aversion to arbitrariness (Navon, 1980); cognitive penetrability (Pylyshyn, 1978, 1980a, 1980b, 1981; Kosslyn, 1981); precision, generality, falsifiability, parsimony, and heuristic value (Kosslyn, 1981); and explanatory adequacy (Kosslyn, 1980; Pylyshyn, 1979). Also included in these articles and others (Kosslyn, Pinker, Smith & Shwartz, 1979; Kolers & Smythe 1979; Kosslyn & Pomerantz, 1977) were repeated definition, clarification, and dispute over the meaning and level of explanation of the concepts of 'analog' and 'propositional'. The overall utility of this debate has been evaluated as a reduction in level of abstraction, greater constraint on theory, and some real convergence of the alternative theories themselves. (Kosslyn, 1981, p73).

Initial empirical evidence brought to bear on the issue was the demonstration of the phenomena of mental rotation. Recent use of experimentation to differentiate between analog and propositional theories has focused round the claim that "...the internal representation upon which mental rotation operates is holistic in that the representation preserves the essential spatial structure on its corresponding external referent". (Shepard & Cooper, 1982, p185). The counter claim is that the representation is schematic, abstracted or reduced in detail rather than holistic. The critical test is whether stimulus features such as complexity can be shown to affect rotational rate. This is predicted by a propositional theory as more information would require more processing because more units would have to be dealt with individually. A holistic representation theory would assume that all information is encoded to the same degree and operations on it would take equal time.

The initial testing of this hypothesis (Cooper, 1975) showed no complexity effects. One experiment produced a linear increase in response time with increasing orientational difference of test stimuli in a task involving discrimination of same from mirror stimuli given an initially learned standard. A second experiment showed a linear increase in preparation time with increasing goal orientation in a task where subjects were given information as to the identity and orientation of the test stimulus. In both experiments the perceptual complexity of the stimuli was defined as variation in number of points of inflection on random two-dimensional shapes of low verbal association value: Attneave Polygons.

To eliminate the counter argument that these experiments provided no indication of whether the full spatial structure of the stimuli was preserved in their internal representations, an extension of the second task was performed requiring discrimination of standard target stimuli from distractors made by randomly perturbing the memorized shape and of equal judged similarity to the standard stimuli. (Cooper & Podgorny, 1976). Again no complexity effect on rotational rate was found, even though the task required use of a very precise mental representation.

These experiments have been criticised on the methodological point that more 'complex' stimuli had more points perturbed in them and thus "...a smaller number of points would have to be remembered for complex shapes to achieve the same probability of detecting a distractor". (Anderson, 1978, p262). Also selection of distractors of equal rated similarity to targets equalizes the complexity of the task even though stimuli may appear to differ in complexity (Pylyshyn, 1977, p27). Cooper and Shepard have defended the experiments (Shepard & Cooper, 1982, p177) on the grounds that the optimal strategy, given that subjects had no advance knowledge of the nature of the distractors, was to preserve as much information about the standard stimulus as possible. However Anderson called for an experiment using distractors with the same number of points perturbed by the same amount, and thus distractors of greater similarity for more complex stimuli.

Shwartz is reported to have performed just such an experiment (Shwartz, 1979, detailed in Kosslyn, 1980, p290-300, 321-322). Although details of results are rather sparse, it appears that for preparatory rotation times there were significant rotation and complexity effects but for more complex stimuli no greater rate of rotation was found. Kosslyn suggests that either encoding was more difficult for more complex stimuli or that "...subjects had more difficulty in defining the bounded region prior to beginning the rotation, that fading reduced the effective difference in complexity as images were rotated farther, or any number of other things". (Kosslyn, 1980, p299). Unlike previous experiments which found no variation in discriminative reaction time with test stimulus orientation after a preparatory rotation, there was a rotational effect for same judgements. It was speculated that this was due either to subjects not fully rotating in the preparatory stage, fading of images with rotation, or a higher response criterion for same responses at greater orientations from the norm.

Kosslyn also briefly reported another study aimed at "...once for all..." determining whether more complex stimuli rotate at a slower rate (Kosslyn, 1980, p302-303). This experiment differs from those previously described in relying totally on timed introspection for its data without any empirical test of the veridicacy of subjects' claims to be performing the required task. Measurements were taken of the time to form an image given a description of how to "see" a presented stimulus and of the time to subsequently rotate it either 60^{o} or 120^{o}. Complexity was manipulated by varying the number of lines and shapes within stimuli and by using ambiguous geometric shapes that were described as either a set of contiguous forms or a set of overlapping simpler forms. Image generation time was greater for more complex stimuli and a rotation effect occurred. Although more complex figures had a greater rotational time, their rate of rotation was not affected by complexity. This was seen as being a consequence of subjects regenerating images at the outset of rotation.

Potentially a demonstration of stimulus complexity effects on rotational rate exists within the work of Shepard and Cooper and co-workers. Their studies have produced vastly varying rotation rate estimations, three dimensional twisted torsi (eg. Shepard & Metzler, 1971) rotating much slower (60^{o}/ second) than two dimensional Attneave random polygons (eg. Cooper & Podgorny, 1976; 400^{o}-500^{o}/ second). The argument can be made that the three dimensional stimuli are more complex forms containing more spatial information and thus that a theory of mental rotation as proposition transformation successfully predicts the slower rate due to a greater computational load. A major hinderance to such a contrast between the two stimuli types is the fact that a simultaneous presentation paradigm has been used with the three dimensional twisted torsi and a successive presentation paradigm with the two dimensional stimuli.

One briefly reported experiment (Podgorny, 1975;

covered in most detail in Cooper & Shepard, 1975, p133-134), attempted to manipulate stimulus dimensionality while holding all other factors constant. This was done by comparing rotational rate for three dimensional twisted torsi and two dimensional versions of them (outlines only). Comparing the two experimental paradigms, simultaneous presentation was found to produce greater slopes and intercepts. This was attributed to use of a feature-by-feature encoding, rotation and comparison strategy. Using the same experimental paradigm and subjects a small difference between the two stimulus types was reported.

Another unpublished experiment (Cooper & Farrell, reported in Shepard & Cooper, 1975, p133-134 and Shepard & Cooper, 1982, p179) found no dimensionality effect on slope using perspective cube shapes drawn to appear either two or three dimensional. Eye movement studies have found differences in dimensionality to effect only the search and confirmation stages and not the transformation and comparison stage using three dimensional twisted torsi and dot representations of their outlines. (Carpenter & Just, 1978, p122-123). One is thus left with the conclusion that an unexplained factor contributes to the differences in rotational rate of two dimensional Attneave polygons and three dimensional twisted torsi. This factor has not been clearly established as being dimensionality or complexity of spatial information. To draw any theoretical conclusions about stimulus complexity effects from this series of experiments is premature.

In contrast, the first experiment to show a stimulus property effect on rotation rate was that of Hochberg and Gellman. They provided the most explicit account of the relevant stimulus properties affecting rotation with the concept of "saliency of landmark features". This is defined as "...cues to location and orientation that are unique and visible from a distance". (Hochberg & Gellman, 1977, p23). It was stressed that landmark features provide 'direct information'. Factors such as cue uniqueness, cue redundancy, peripheral or foveal visibility of cues and masking effects were theorized to contribute to a gestalt interaction affecting the ease with which an integrated view of a stimulus was built up in successive glances. By varying the saliency of these landmarks in stimuli, the rate and time of rotation was manipulated in a task requiring discrimination of stimuli from simultaneously presented misoriented versions and their mirror images. It was theorized that the results were not due to complexity, per se, but due to more comparisons being made for non-saliently - landmarked stimuli because of the inaccessibility of their informative features. Although this paper is often cited as supporting a propositional representation theory, no comment is made of this issue in it.

Zeno Pylyshyn conducted two experiments to explicitly investigate the issue (Pylyshyn, 1979). The experiments required judgements of whether a misoriented test stimulus was an embedded subfigure of a simultaneously presented target stimulus. Distractors in one experiment were mirror images of test stimuli, and in the other were inappropriate figures with two thirds of their component lines matching parts of the target figures. Manipulation of the gestalt 'goodness' or figural integrity of the test stimulus was shown to affect rotational rate as was the overall difficulty of the comparison at each trial. This was seen as evidence of analysis of the original stimulus and a piece-by-piece rotate-and-compare strategy. These experiments and their interpretation have however been subject to severe methodological criticisms because of the differences in experimental paradigm and stimuli used from those typically used in a mental rotation task (Kosslyn, 1979, 1981; Shepard & Cooper, 1982, p177-178).

A recent experimental series (Yuille & Steiger, 1982) also showed figural complexity manipulations to affect rotational rate. The stimuli used were variations of the three-dimensional twisted block torsi introduced initially by Shepard. One experiment involved simultaneous presentation of a standard and vertically rotated test stimulus with discrimination of mirrored from standard test stimuli. Complexity was manipulated by informing subjects of a figural redundancy. (The bottom half of the stimuli provided all the information needed). Subjects with this information had significantly reduced rotational rates. Further manipulation of complexity was by addition of blocks to the stimuli. Simultaneous discrimination of standard from mirrored stimuli (a task where figural redundancies could be exploited) was at a greater rate than in a task requiring attention to all stimulus features. (Achieved by added distractors with segments twisted out of alignment with those in the standard by 90%). These demonstrations of processing limits in performance, in both between and within subject designs, were taken as consistent with a feature analysis or piece-meal sequential comparison of figure-segments interpretation of mental rotation rather than a holistic template matching interpretation.

One strong methodological criticism which can be made of all the preceding experiments purporting to demonstrate complexity rotational-rate interactions revolves around their use of simultaneous presentation of standard and test stimuli. A detailed investigation of this paradigm has been made using eye-fixation data as the dependent variable. (Just & Carpenter, 1976; Carpenter & Just, 1978). This was shown to be a more sensitive measure than overall discrimination reaction time as it could be decomposed into a sequence of processing stages. Three such stages were uncovered: Search, Transformation and Comparison, and Confirmation. All stages showed an orientation effect. However complexity effects were shown to be limited to the processes of searching for corresponding segments of a stimulus to transform and confirming the congruency of the stimuli after transformation. Chronometric analysis of overall reaction time in this simultaneous presentation paradigm is unable to decouple encoding and decision stages from the transformational stage and thus does not allow any decision to be made about effects of stimulus complexity on the rate of rotation. Shepard and Cooper have dismissed such studies on this ground. (Shepard & Cooper, 1982, p178).

Another criticism is that the simultaneous presentation paradigm does not allow firm conclusions to be drawn about mental imagery as it does not necessarily require formation and manipulation of a purely internal representation. On this ground Kosslyn has rejected the theoretic conclusions drawn from such studies, dismissing them as 'domain contamination'. (Kosslyn, 1980, p301). The importance of distinguishing between operations on the visual code (as used in a simultaneous presentation condition) and visual images (used in successive presentation) is highlighted in a recent series of experiments on rotational transformations of the visual code which detailed significant differences in processing mechanisms for 'same' and 'different' judgements. (Simon, Bagnara, Roncato & Umilta, 1982).

In fairness, the simultaneous presentation paradigm is a replication of that used in the original studies from which the holistic analog mental rotation process theory was postulated. The range of experimental paradigms used by Shepard and co-workers extends as far as the demonstration of rotational effects in the purely perceptual phenomena of the breakdown of apparent motion (Shepard & Judd, 1976; Robins & Shepard, 1977; Farrell & Shepard, 1980). The varied methodology of Shepard's work has been interpreted as providing strong convergent validation of the basic theory, unified by the concept that many cognitive processes resemble perceptual processes and that a continuum exists from the perceptual to the purely imaginal. Thus similarities occur at different 'levels of processing' and are indicative of basic mental operations and structures and differences highlight the transformations in information which occur with mental 'depth'. (eg. Shepard & Podgorny, 1978; Finke, 1980).

Those studies failing to demonstrate complexity effects have been criticised for failing to effectively manipulate stimulus complexity. Also those reported by Kosslyn, although covered in insufficient detail in his book to allow detailed methodological examination, seem on his own admission to have failed to isolate the processing stage and nature of complexity effects. Anderson's indeterminacy is illustrated by one series of studies having not fully addressed representation and the others inadequately handling processing.

CHALLENGING THE INDETERMINACY PROBLEM: STERNBERG'S ADDITIVE FACTORS LOGIC

An obvious synthesis is to use a successive presentation paradigm while implementing stimulus manipulations similar to those which have shown some 'complexity' effect. To attempt to further overcome the possible shortcomings of previous experimentation, a more powerful experimental paradigm capable of resolving the issues of representation and processing is available. It is the Additive Factors Method, as developed by Saul Sternberg. (Sternberg, 1966, 1967, 1969a, 1969b; Pachella, 1974; Seymour, 1979, p10-24). This is a paradigm whose deductive logic is capable of providing a conceptualization of the sequence of cognitive processes. Such processing stages are assumed to occur in a constant linear sequence, independent in duration of each other, each receiving an input, transforming it and outputting it to further stages. If different experimental manipulations can be shown to produce independent additive effects on reaction time then they are seen as having affected different stages. Conversely interacting manipulations are seen to be affecting a common stage. The nature of each unique stage is deduced from the type of manipulation affecting it. Additive factor experiments are thus multifactorial and can be conceived of as a series of converging operations.

The need for such an approach is highlighted in the following quotation dealing with the Cooper and Shepard 1973 experiments: "If ROTATION is a processing stage interposed between the initial ENCODING and RETRIEVAL stages and a subsequent COMPARISON stage the effects of test symbol orientation should combine additively with effects due to factors influencing the other stages. This prediction was not rigorously tested by Cooper and Shepard, since their experiment did not incorporate a stimulus quality factor likely to influence ENCODING or a memory set size factor likely to influence COMPARISON". (Seymour, 1979, p63). What has not been made clear is whether rotation occurs on encoding of the test stimulus, before comparison with memorized representations, or during those comparisons.

Assuming that a unique rotation stage exists and that images are encoded preserving all their essential spatial structure, the following experimental manipulations would be predicted to each affect a unique processing stage:

(1) stimulus quality (ENCODING)

(2) orientation of test stimuli (TRANSFORMATION)

(3) memory load (COMPARISON)

(4) response type (DECISION)

A propositional processing theory predicts an interaction of stimulus quality and test stimulus orientation as ease of encoding a stimulus and amount of information encoded would affect the load on a transformation stage. The response type factor indicates the use of two types of misoriented non-match type test stimuli; mirror images of the standard stimuli and totally different stimuli. This allows determination, in a within-subjects design, of whether the encoding stage provides sufficient rotationally invariant information for discrimination of a totally different stimulus from the standard without a rotational correction. No test stimulus orientation effect on non-match different test stimuli is predicted by such a theory.

A balanced replication of this modified Additive Factors task with high and low imagery subjects provides an additional manipulation adding deductive power to the design. Group differences would highlight where mental imagery is functionally important and group similiarities where processes not dependent on imagery act.

Using the Additive Factor Method in a mental rotation experiment is in part a replication of an earlier study which showed a transient rotation effect rapidly replaced by the strategy of verbal encoding based on rotationally invariant stimulus features. (Shinar & Owen, 1973). Rotation was isolated as effecting the speed of a comparison stage because reaction time data showed differences in slope with orientation at varying memory loads, but a common intercept (suggesting equal precomparison activities). Two factors detract from this study however. Firstly the stimuli used were Attneave Random Polygons chosen on the basis of "...highly judged dissimilarity among the patterns in all orientations used". (Shinar & Owen, 1973, p150). Such a choice makes a verbal recoding strategy optimal, hence little light is shed on the nature and use of visual imagery. More importantly, the 'different' test stimuli used on each trial were stimuli other than the memorized standard. (As compared with the more common use of mirror-image 'differents' or highly similar distractors). Later studies have shown that test stimulus orientation has no effect in such 'identification' tasks, suggesting a feature extraction encoding process occurs making subsequent transformations redundant. (Corballis, Zbrodoff, Shetzer, & Butler, 1978; Corballis & Nagourney, 1978; Eley, 1982). Mirror image 'differents' make the task sufficiently difficult and required a rotational transformation to correct the test stimulus image before comparison with the memorized standard becomes possible. The paper acknowledged that the data reflected a different process from the Shepard and Metzler mental rotation process (Shinar & Owen, 1974, p154). This is reflected in the discussion being subtitled "The Development of Shape Constancy" rather than relating its results to the issues of imagery representation and processing.

CHAPTER II

METHOD

AIMS

A multifactional experiment based on Additive Factors logic was devised in an attempt to produce interpretable behavioural evidence capable of refuting Anderson's claim of an indeterminacy of representation and process in the study of mental imagery. A mental rotation task was used as it has been seen as a critical experiment backing both sides of the theoretical debate on whether images are processed and represented Propositionally or in an Analog Holistic manner. The focus was to test (a) for the existence of a rotational stage discrete from encoding and decision stages and (b) for the effects of 'feature saliency' on the functional image representation.

STIMULI

The stimuli used were randomly generated two-dimensional outline polygons adapted from those presented in Vanderplas and Garvin, 1959. (See Appendix 1 for the stimuli used in this experiment). Specifically they were shapes 23, 27, 28 and 29 of the six point shapes presented in their Figure 3 (Vanderplas & Garvin, 1959; p149) and shapes 21, 22, 25 and 28 of the eight point shapes presented in their Figure 4 (Vanderplas & Garvin, 1959; p150). According to Vanderplas and Garvin all the shapes come from a group having low verbal-association value. Although these stimuli come from two different sets, some stimuli have small angles (less than 5^{o}) in parts of them which are not readily evident and all could be treated as having approximately the same number of easily discriminable sides. Thus all shapes would be at nearly the same level of 'complexity' according to the definition of complexity as number of sides used in the mental rotation studies of Cooper 1975 and Cooper and Podgorny 1976. Attneave, 1957, identified the following physical properties of stimuli as correlating with complexity judgements:

(a) number of points perturbed.

(b) mean difference in angle between successive turns in symmetry.

(c) mean difference in angle between successive turns in contour.

Given that these stimuli are of approximately equal 'complexity' and that this is the critical factor in the formation of a mental representation, both Analog and Propositional theories of mental rotation make equivalent predictions ie. equal time spent in ENCODING operations and equal rates of rotational TRANSFORMATION for all stimuli.

However predictions of differences between these stimuli can be derived from Hochberg and Gellman's 1977 theory that the 'saliency of landmark features' effects the timing of mental events during a mental rotation task. Their experiment involved a simultaneous presentation paradigm (with the inherent weakness of being unable to separate out processing stages) and stimuli carefully designed around their definition of 'landmark feature saliency'. They interpreted their demonstration of varying slope and intercept in a time/angle function as the result of relative inaccessibility of stimulus features and suggest that..."the mental rotation task reflects the processes by which perceived forms are built up over successive glances..." (Hochberg & Gellman, 1977, p25). Thus they seem to be implicating ENCODING as the critical stage affected by manipulating landmark feature saliency. A common interpretation of their work, within a Propositional framework, is that only salient features are encoded and used within the mental rotation task, rather than the whole stimulus in a template-like fashion (eg. Pylyshyn, 1979, p27). One can thus derive a description of the nature of the representation used during mental rotation, according to a Propositional theory. It would consist of landmark features, defined as "...cues to location and orientation that are unique and visible from a distance..." (Hochberg & Gellman, 1977, p23).

However, the stimuli used by Hochberg and Gellman are open to the criticism that they have not been equated for complexity and that this, rather than 'landmark feature saliency', accounts for the data. They answer this criticism with the statement that "This difference is not due to complexity, per se,... inasmuch as Cooper (1975) found no such effects with the Attneave-Arnoult shapes". (Hochberg & Gellman, 1977, p25). The stimulus set described earlier provides an empirical test of this claim as they are of equal 'complexity' but can be interpreted as differing in 'landmark feature saliency'. Specifically they consist of stimuli with:

(a) very large unique cues to stimulus orientation; a wedge out of them (my stimuli 1, 2, 3 and 4).

(b) small unique cues to stimulus orientation; a nick out of the tops of them (my stimuli 5 and 6).

(c) stimuli with no obvious landmark features being nearly symmetrical and having no obvious indentation (my stimuli 7 and 8).

Given the validity of such a straightforward interpretation of 'landmark feature saliency' a Propositional theory would predict definite stimulus differences in ENCODING and in TRANSFORMATION while a Holistic theory predicts stimulus differences during ENCODING only.

APPARATUS

The experiment was conducted "on-line" by an Apple Two Plus micro-computer with black and white video monitor. (CCTV Monitor, Model number TVM-IO. The screen size is 19 cm x 14 cm of which a 12 cm x 12 cm area was used). The computer controlled the timing of events, presented pre-selected stimuli, stored chronometric and error data, and provided subjects with feedback as to their accuracy and progress at the task. (For further documentation of the controlling program see Appendix 2). Subjects sat at a table in a quiet darkened room a 140 cm from the monitor which was 100 cm above floor level. Contrast and brightness of the monitor were turned down until the decay rate of images was unnoticable. Morse keys were used for same/different responses and a push button to indicate completed memorization of the to-be-remembered stimulus set.

OVERALL DESIGN

The following factors were manipulated:

(1) Imagery Ability - Two extreme groups of subjects according to Marks 1972 Vividness of Visual Imagery Questionnaire.

(2) Memory Load - From one to four stimuli were in the memory set which was held at a constant size during an experimental session. Different stimuli were used on each trial.

(3) Stimulus Landmark Feature Saliency - Eight different stimuli were involved sampling three levels of stimulus landmark feature saliency. (But see the note on mirror-image substitution).

(4) Test Stimulus Orientation - Orientation varied from 0^{o} to 240^{o} in steps of 60^{o}.

(5) Type of Match - The three levels involved were; matches, non-match mirror images and non-match differents. However only a binary response was required. (Match or Non-match).

(6) Subjects - Four subjects per group.

A pictorial representation of the design can be seen in Appendix 3.

TRIAL SEQUENCE

Each trial began with an Auditory Warning Signal (the standard Apple II 'bell' sound) followed by a .5 second delay. Then memory set stimuli were presented and a software timer started. Subjects controlled the duration for which these stimuli were presented with a button over which their left hand rested. Pressing this cleared the screen and stopped the timer from which memorization time was read. The timer was reset and restarted and the test stimulus then presented. Subjects indicated whether this stimulus matched the one in the memory set by pressing one of two telegraph keys, labelled 'same' and 'different', with their right hand. Pressing either key terminated the display of the test stimulus. A maximum of three seconds was allowed for this discriminative reaction. If either this time was exceeded, a wrong response was made or a response was made in under five milliseconds then an appropriate error message ("TOO SLOW", "WRONG RESPONSE", "ANTICIPATION") was displayed in the centre of the screen for three seconds. Finally a fixation cross was displayed in the centre of the screen. Along with this was a line at the bottom left of the screen, which grew in length with trials completed, to ultimately join with a dot at the right side of the screen, indicating total number of trials in the session. An inter-trial interval of from one to five seconds occurred as data was moved from timer variables to an ordered storage array, errors were recorded for re-presentation and the display for the next memory set stimuli and test stimulus was calculated.

MEMORIZATION TIMING

In an attempt to ensure that the degree of encoding of memorized stimuli was equivalent at all levels of memory load, subjects controlled the exposure duration of the to-be-memorized stimulus set. This procedure follows that used by Shinar and Owen, 1973. Using the alternative method of experimenter control of memorization time opens up the possibility that any increase in discriminative reaction time with greater memory load may reflect only weaker encoding of memorized stimuli rather than a memory search process. The time subjects spent viewing the memory set was recorded to allow empirical checks on the effectiveness of this procedure.

RESPONSE BALANCING

The number of positive and negative responses were balanced to remove any possibility of response bias. This was achieved by including in the test set:

(a) two presentations of a match for all eight stimuli at each of the five test orientations (2x8x5 = 80 matches).

(b) one presentation of a mirror image of each stimulus at each orientation in situations where their non-mirrored images occurred in the memory set (8x5 = 40 non-match mirrors).

(c) Fourty presentations each stimulus at each test orientation in situations where no version of them occurred in the memory set (8x5 = 40 non-match differents).

TRIAL ORDER

Randomization of trials within a session was made with regard to orientation of the test stimulus and type of match situation. The same stimulus at the same orientation was never presented twice in a row, regardless of match type. The same random order was presented to all subjects within each memory set block.

CONSTRUCTION OF THE MEMORY SET

In constructing the to-be-remembered stimulus sets the primary focus was on selecting stimuli to be 'targets' for the test stimulus. Having selected these, additional stimuli had to be chosen to fill out the set when the memory load was more than one. The additional stimuli were selected randomly from the remaining seven stimuli in such a way that each stimulus was presented an equal number of times overall. Position of each stimulus within the displayed memory set was randomized so stimulus position provided no cue to the identity of the test stimulus. The same randomly selected sets of to-be-remembered stimuli were used for all subjects.

DISPLAY PLACEMENT

With a memory load of one, the quarter of the screen in which the to-be-memorized 'standard' stimulus appeared was randomly selected at each trial. Positions at which the standard stimuli were displayed for the other memory loads are shown in Appendix 4. All display positions were chosen so that the centres of the stimuli were equally displaced from the centre of the screen. This was done to force subjects to move their eyes to the centrally placed test stimulus and eliminate the cues of decaying images on the screen. (A pre-test showed the necessity of this: with centrally displaced stimuli and rapid pressing of the memorization button there was the impression of a plastic transformation of the two overlapping images similar to the apparent motion phenomena. Displacing all memorized stimuli away from the centre of the screen and placing a ten millisecond delay between offset of the memory set and onset of the test stimuli eliminated this).

MIRROR IMAGE SUBSTITUTION

Pre-test subjects reported learning that mirror image test stimuli were distinctly different from those used in the memory set because they faced a different way. The optimal strategy was to rehearse names for each memory set stimulus and respond 'different' if they did not appear. Mirror images were as easy to detect as totally different stimuli and encoding of the memory set did not require mental imagery. The superficial cue of stimulus facing was being used as the basis for the discriminative response.

The stimulus sets were thus changed to make the use of mental images a more likely strategy and to prevent learning of a distinctive set of mirror image test stimuli. On half of all trials (randomly selected) memory set stimuli and the corresponding set stimulus were changed to their mirror images. The non-match mirror condition then involved a test stimulus that was a mirror image only as far as that trial was concerned. It was assumed that this mirror image reversal was trivial ie. that the information processing involved in detecting a match between a shape and itself is equivalent to that required to detect the match between the mirror image of that shape and its mirror image.

SUBJECTS

Subjects came from the upper and lower five percentile group of 156 second year Psychology students who were all administered a self-report test of mental imagery, the Vividness of Visual Imagery Questionnaire. (Marks, 1973, Gur & Hilgard, 1975). The low imagery group consisted of three females and one male; the high imagery group two females and two males. All subjects were right handed and had normal vision. Subjects were paid for their participation in the experiment.

INSTRUCTIONS AND PRACTICE

Subjects were told the aim of the experiment was to "investigate their mental imagery". At no stage during the experiment was any specific strategy suggested to subjects although it was demonstrated how misoriented stimuli were rotations of upright ones. They were told the task was trying to stress their abilities and may be very difficult.

Initially the sequence of events within a trial was explained and demonstrated to subjects. Specifically they were shown how to depress the push button with their left hand to end stimuli memorization and cause the onset of test stimuli. It was stressed that subjects had to form an accurate image of the memorization stimuli as they would be tested in detail. It was also stressed that the discriminative reaction on presentation of the test stimulus must be both quick and as accurate as possible. The three second limit was explained as was the procedure of repeating all errors until corrected. Subjects were thus discouraged from adopting a strategy which involved an excessive trading of accuracy for speed.

First practice was given at discriminating the stimuli from their mirror-images until all had been correctly discriminated twice. The full procedure was then introduced. This required responding 'same' only to matches of the memorized stimuli, regardless of test stimuli orientation and responding 'different' to both mirror-image non-matches and different non-matches. Practice was given on a block of 16 trials randomly sampling each type of response. This was repeated until each subject made two error free runs. After this the added complication of varying memory set was explained and subjects began the experiment. All subjects were required to repeat this block of 16 to the 100% success criteria as a 'warm-up' before starting each experimental session.

CHAPTER III

RESULTS

MISSING DATA REPLACEMENT

Subject five (high imagery group, female) was unable to complete re-presentation of trials on which errors occurred due to time limitations on her last experimental session. Given the large amount of data collected from this subject and the unavailability of another high imagery subject missing values were replaced statistically. Of the 33 missing values (out of a total of 160) 14 occurred on match trials and were replaced with the equivalent value from the first presentation of each condition (recall each match stimulus was presented twice at each orientation). Preliminary analysis of other subjects' data showed no significant orientation effect for non-match different responses and so the 14 missing values in this category were replaced with the average value for each stimulus over all conditions. All five non-match mirror image values were replaced with the mean value for the particular stimulus and test orientation involved. Mean memorization times at each memory load and for each stimulus at memory load one were calculated from the obtained data only.

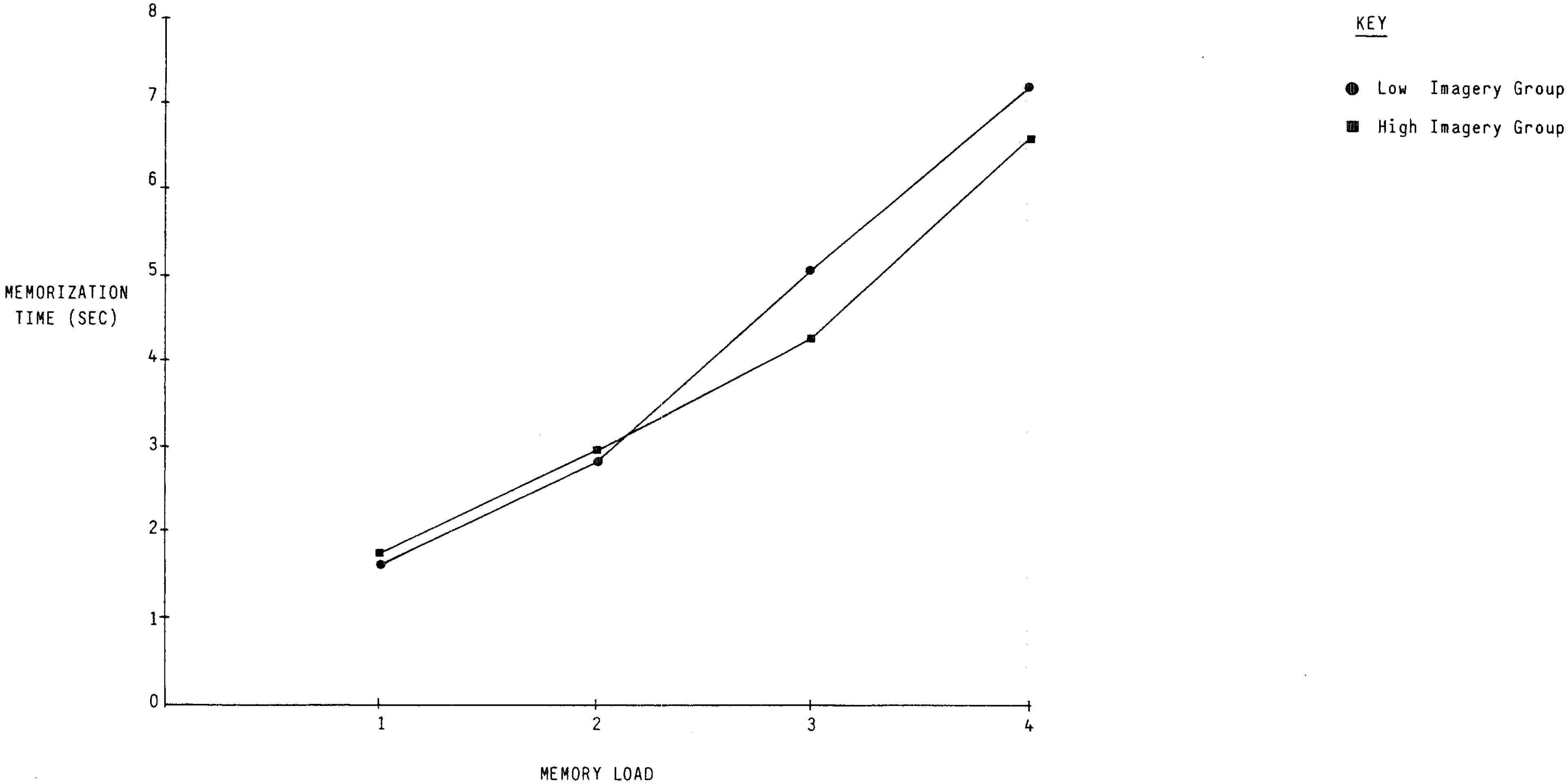
MEMORIZATION TIMES

To test empirically that the degree of encoding of memorized stimuli was equal at all levels of memory load mean memorization times were calculated for each subject within each memory set. Times less than ten milliseconds were classified as resulting from procedural errors and were not included in data analysis. Such outliers occurred due to the accidental triggering of the button indicating completion of memorization before the to-be-memorized set was displayed and made up less than 2% of any memory load block. Corrected mean memorization times were treated by an Imagery Groups x Memory Load x Subjects ANOVA with repeated measures on the Memory Load Factor. Only the Memory Load Factor was significant $F\ (3,18) = 15.51$, $p<.001$. Trend analysis showed only the linear trend to be significant. ($F(1,7) = 90.91$, $p<.001$). Figure 2 shows a graphic representation of these results.

The memory load condition involving memorization of only a single upright stimulus provided potentially interpretable data on the encoding time for each individual stimulus. Mean memorization times, excluding anticipations were calculated for each subject at each stimulus by $F\ (7,42) = 2.7$, $p<.025$. Inspection of mean memorization times averaged over all subjects showed the pattern of data to vary greatly from apriori predictions of data ordering according to Feature Saliency. Subsequently post hoc multiple comparisons were made using the Least Significant Difference method. (Keppel, 1973, p135). Results of this analysis are presented diagramatically in figure 3. No distinctly separate stimulus groupings are apparent.

The Least Significant Difference method used for the above post hoc multiple comparisons provided no correction for experiment-wise error rate (arising from

FIGURE 2



Graph showing mean memorization times for high and low imagery groups at each memory load

FIGURE 3

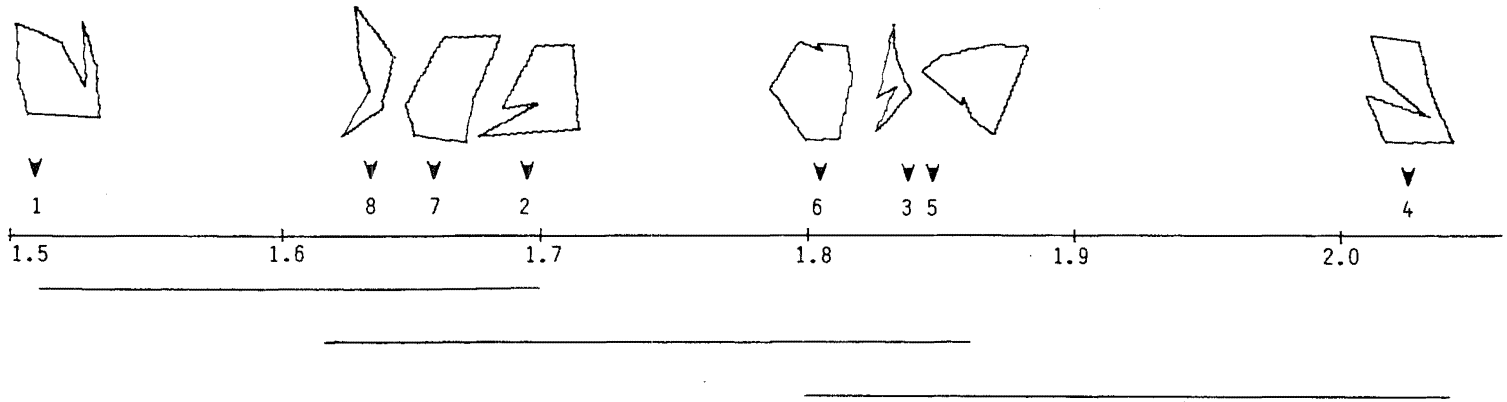


Diagram showing mean memorization times for each stimulus in the condition where only one stimulus was memorized. (Underscoring indicates stimuli between which there is no statistical difference at the .05 level according to the Least Significant Differences method).

increasing possibility of Type I errors with increasing number of comparisons). All recommended methods of correcting for the probability of such false alarms set critical values so large that no significant stimulus differences were detectable. The error term used in calculation was the $MS_{\text{Stimulus x Subjects}}$ calculated from a Stimulus x Subjects ANOVA which pooled data over the non-significant Imagery Group factor. (This follows Kirk, 1968 and Winer, 1962, but not Keppel, 1973). Thus even an extremely liberal statistical method was unable to identify different stimulus groups during memorization.

STIMULUS SALIENCY

Analysis of error and reaction time data initially proceeded with an Imagery Groups x Memory Load x Match Type x Stimulus Feature Saliency x Test Stimulus Orientation ANOVA. However the results from this overall ANOVA, subsequent similar analyses, and an examination of mean values showed the Saliency factor to be performing in a manner which could not be accounted for by the theorized ordering of its levels. (Results from the overall ANOVA and mean values can be inspected in Appendix 5). These levels of landmark feature saliency had been created by collapsing data over presumably similar stimuli to give three groups, those with:

(1) large unique features.

(2) small unique features.

(3) no obvious 'landmark' features.

This, combined with the lack of any distinct stimulus grouping for memorization data, suggested that the stimulus manipulation had been ineffective and subsequently data for individual stimuli was examined.

Stimulus differences in error rate were investigated by an Imagery Groups x Stimuli x Subjects ANOVA with data summed over the Memory Load, Type of Match and Orientation factors to give the total number of wrong responses made for each test stimulus. This analysis produced no significant results. From this it can be concluded that the attempted manipulation of landmark feature saliency did not effect the difficulty of mental operations.

Stimulus differences in reaction time data were investigated using only values from the matching test stimulus condition as the clearest orientational effect consistant with a rotational transformation occurred within this data, as will be detailed later. An initial attempt at analysis was made with an Imagery Groups x Memory Load x Stimulus x Test Stimulus Orientation x Subjects ANOVA but this revealed a significant Memory Load x Stimulus interaction, $F(21,126) = 1.89$, $p<.025$. Therefore separate Imagery Groups x Stimuli x Test Stimulus Orientation x Subject ANOVAS were calculated at each memory load. Significant stimulus main effects were detected only with memory loads of one, $F(7,42) = 5.11$, $p<.001$, and two, $F(7,42) = 3.01$, $p<.025$. (At all memory loads highly significant orientation effects were present, the smallest $F(4,24)$ being 13.40, $p<.001$). No stimulus x orientation interactions reached significance indicating that there was no difference between stimuli in the rate at which they were rotated. Examination of mean values for each stimulus at memory loads one and two (see Table 1) shows

TABLE 1

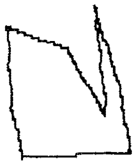
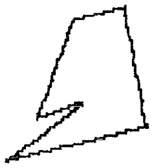
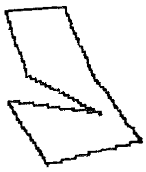
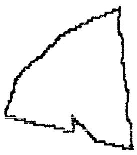
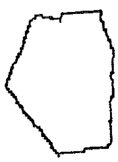
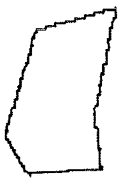
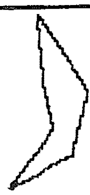
STIMULI		MEMORY LOAD 1	MEMORY LOAD 2
#1		1250	1474
#2		1288	1472
#3		1590	1463
#4		1529	1635
#5		1626	1738
#6		1515	1574
#7		1432	1567
#8		1277	1420

Table showing mean reaction times for stimuli at memory loads of one and two. Stimuli are arranged in their hypothesised order of complexity.

that the hypothesised order of landmark feature saliency fails to predict discriminative reaction times. Indeed stimuli from hypothesised opposite extremes have the most rapid reaction times. Furthermore the relative placing of stimuli is not consistent over memory loads.

From the preceding analysis it is apparent that the attempt to operationalize the theory of landmark feature saliency has been unsuccessful. To proceed to localize the saliency effect at any information processing stage or stages and compare predictions of propositional and holistic theories of imagery is therefore not possible. In subsequent analyses data were collapsed over stimuli. The focus of the following analysis is in determining the flow of information processing during the task.

DISCRIMINATIVE REACTION TIMES

Hypotheses

Several strong a priori hypotheses can be made about discriminative reaction times in this task on the basis of results common to many mental rotation experiments. The strongest expectation is that response times for both match and non-match mirror image test stimuli will increase with orientation away from the upright. Also times for mirror image test stimuli should be longer, reflecting an additional decision step after rotation to test for a match. In contrast for non-match different test stimuli no increase in times with orientation is expected, replicating in part the results of Shinar and Owen 1972. This result would reflect orientation independent identification processes which have also been found in experiments using a misoriented stimulus identification paradigm. (eg. Corballis, Zbrodoff, Shatzer & Butler, 1978; Corballis & Nagourey, 1978; Eley, 1982). Combining these predictions for the different type of match an interaction between the Type of Match and Orientation is expected.

Demonstration of a linear increase in reaction times with test stimulus misorientation does not in itself provide evidence for a rotational transformation process. An alternative explanation is that processing misoriented test stimuli is merely more difficult. The inclusion of test stimuli at 120° and 240° orientation provides a critical test between these two explanations. If subjects conduct an internal simulation of an external rotation then this process will have properties of trajectory and direction. With the stimuli at 240° there exists the possibility of transforming them the 'long way' of 240° or of occasionally taking the 'short-cut' of 120°. A difficulty explanation predicts no such differences because of the equivalent absolute differences from the upright of 120°.

Given an equivalent degree of stimulus encoding during memorization (as indicated by the linear increase in memorization times with memory load), Sternberg's typical memory search results can be anticipated ie. a linear increase in decision times with memory load for all types of matches.

Finally a difference between imagery groups was initially hypothesised, although the lack of group differences in memorization times reduces this expectation. Any positive results could be used to deduce subtle differences in information processing strategies between the groups in a post hoc explanation.

Measures Used

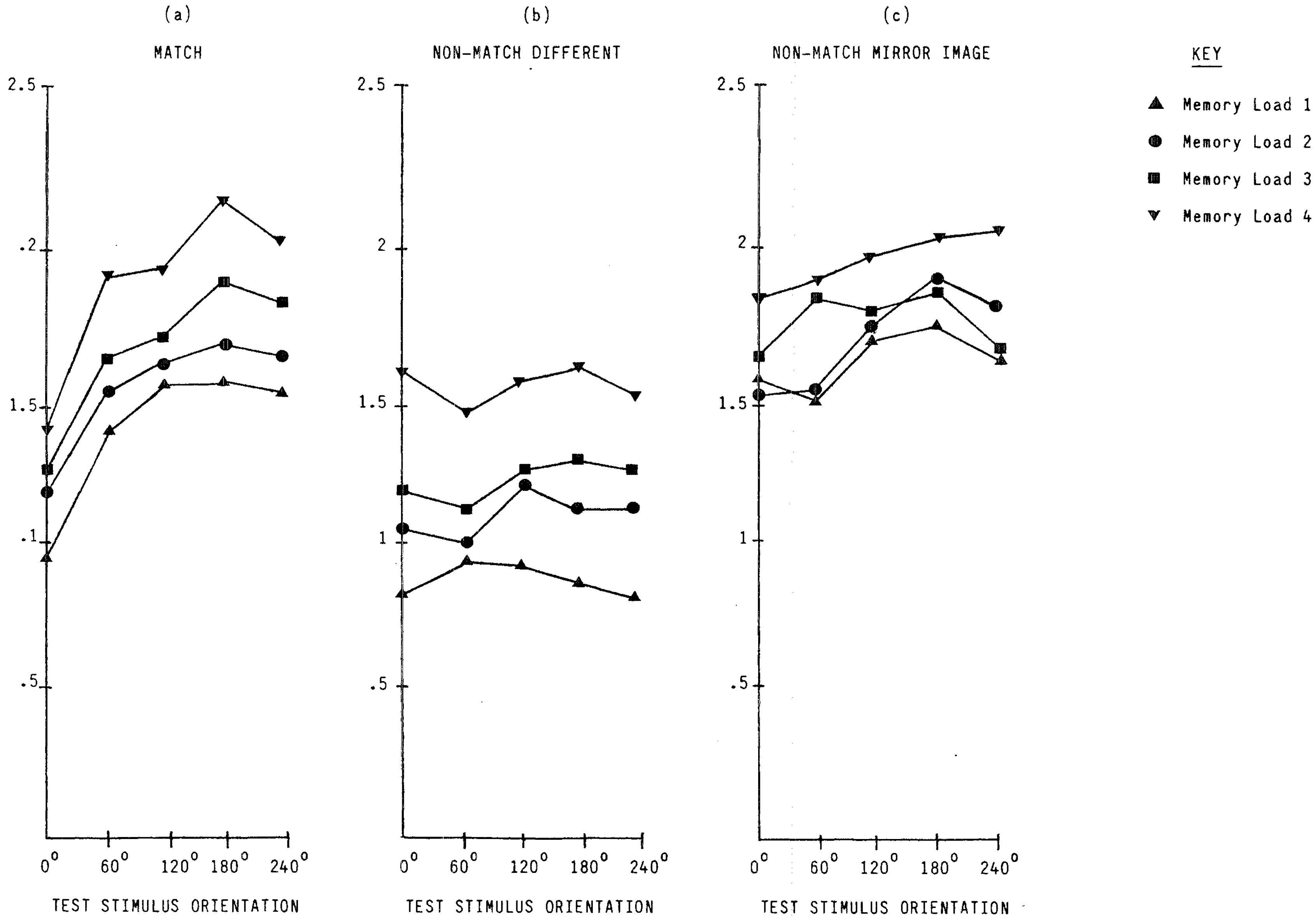
Discriminative reaction time data was initially treated by an Imagery Groups x Memory Load x Type of Match x Test Stimulus Orientation x Subjects ANOVA with repeated measures on all experimental factors except groups. This was performed with data for each subject in each condition collapsed over stimuli by using the mean or the median. As both measures produced similar results that using mean data will be reported as this measure is more strongly additive and more suited to Sternberg type deductions about real time processing durations. (Pachella, 1974, p54).

Overall Analysis

The overall ANOVA revealed a significant Memory Load x Type of Match x Test Stimulus Orientation interaction, $F\ (24,144) = 2.17$, $p<.01$; a significant Type of Match x Orientation interaction, $F\ (8,48) = 14.32$, $P<.001$; and significant main effects for Memory Load $F\ (3,18) = 12.07$, $p<.001$; Type of Match $F\ (2,12) = 34.37$, $p<.001$; and Test Stimulus Orientation $F\ (4,24) = 17.05$, $p<.001$. With the exception of the three way interaction these results were as predicted. Mean values can be seen in Figures 4 and 5.

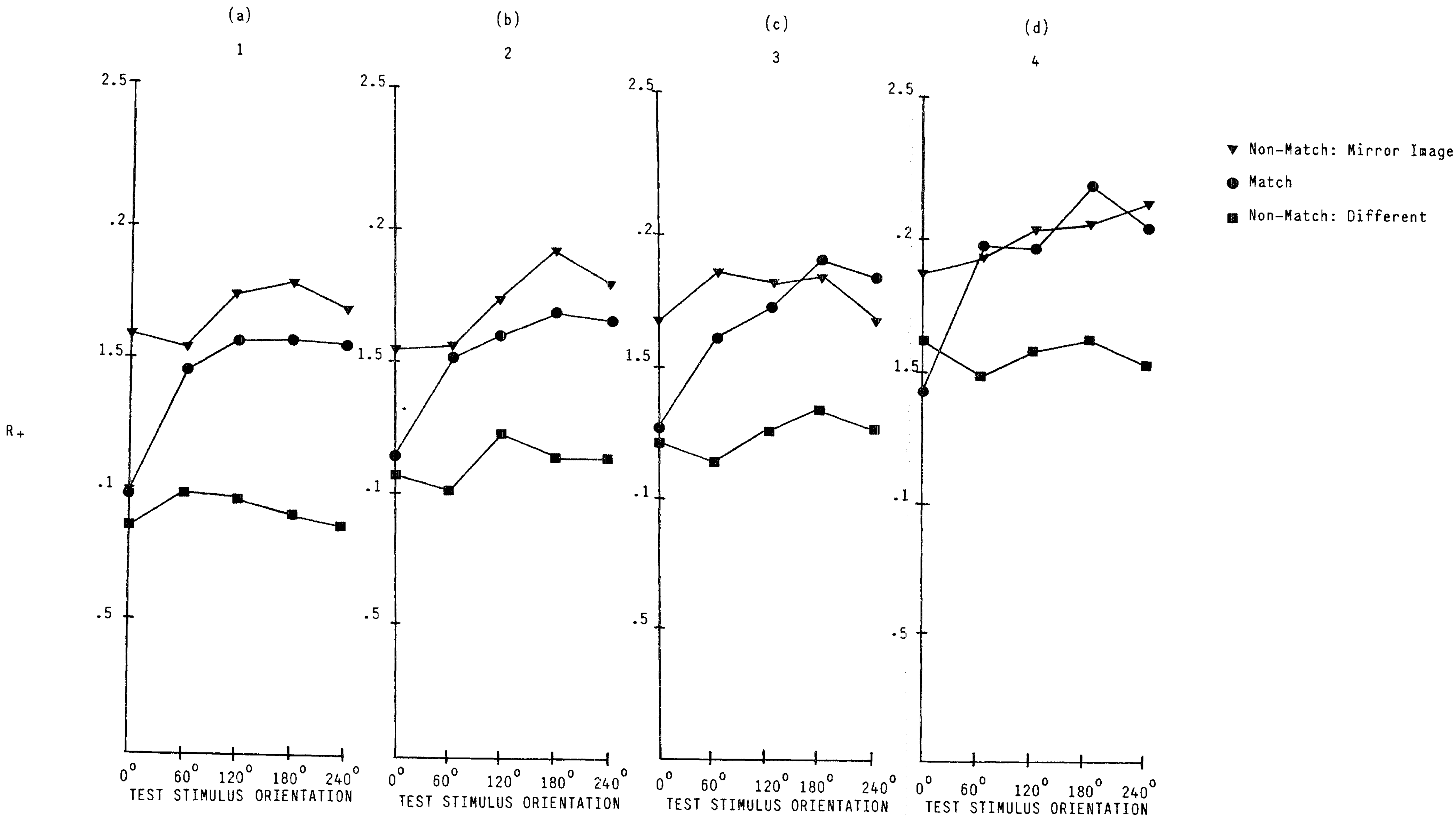
To determine the effects of Memory Load and Test Stimulus Orientation separate Imagery Groups x Memory Load x Test Stimulus Orientation x Subjects ANOVAS were performed for each Type of Match condition.

FIGURE 4



Graphs showing discriminative reaction times across test stimulus orientations for each memory load level at each response situation.

FIGURE 5



Graphs showing discriminative reaction times across test stimulus orientations for each response situation at each memory load

Matching Test Stimuli

With Matching Test Stimuli the only significant factors were the main effects for Memory Load, $F(3,18) = 8.46$, $p<.01$, and Test Stimulus Orientation, $F(4,24) = 29.03$, $p<.001$. Trend analysis over memory loads showed only the linear trend to be significant, $F(1,18) = 24.81$, $p<.001$, and this trend accounted for 97.7% of the variance in this factor. Similar analysis of the orientation factor up to 180° (240° being excluded as it was expected to deviate from the other orientation's pattern) showed a significant linear trend, $F(1,24) = 90.26$, $p<.001$, accounting for 77.7% of the factor variance and a significant quadratic trend, $F(1,24) = 10.76$, $p<.01$, which only accounted for 9.2% of the orientation variance.

In figure 5 it can be seen that match detection with upright stimuli is much quicker than at other orientations and it may be this more rapid 0° responding which contributed to the significant quadratic trend. To test this, a regression equation was fitted to match discrimination times for data from the 60°, 120° and 180° test stimulus orientation conditions and the predicted y intercept (ie. 0° condition value) was derived. The standard error of estimate of the regression equation was used to provide an indication of the size of the difference between the actual value and the predicted value. The actual value was 1.04 standard errors of estimate below the predicted value. Thus although an absolute difference between the predicted value and the actual mean value of 361 msec existed there is only suggestive evidence that 0° matches were detected at an abnormally fast rate relative to the trend at other orientations. The diverse range of times for individuals contributed to the large variance in the regression analysis.

The rapid discriminative response with upright matching test stimuli in the present experiment replicates the pattern of results in the Shinar and Owen experiment (Shinar & Owen, 1973, p151). One hypothesis to account for this data is that the identification process presumed to occur with non-match different test stimuli provides enough information to detect upright matches as well. To investigate whether there was any difference between the matching and non-matching different test stimulus data separate Match 0°/Different 0° x Subject ANOVAS were made at each memory load. These confirmed the lack of any significant difference, except with a memory load of four where times for matches were actually faster than those for non-match differents, $F\ (1,7) = 9.94$, $p<.025$. (See figure 5 (d)).

To determine if the linear increase in match response times with orientation showed characteristics unique to a rotational transformation comparison of data for the 120° and 240° test stimulus orientation conditions was made by an Orientation x Subjects repeated measures ANOVA. Data values were produced by averaging over stimuli and memory load conditions. (Previous analysis having shown memory load to have an additive effect for match responses). This showed responses for the 240° condition to take significantly longer, $F\ (1,7) = 16.91$, $p<.01$. Visual comparison of the data distribution over orientations shows the 240° condition to be skewed towards longer response times than those of the 120° condition.

(See figure 6). These results support the contention that a rotational transformation is evident in match response data.

Non-Match Different Test Stimuli

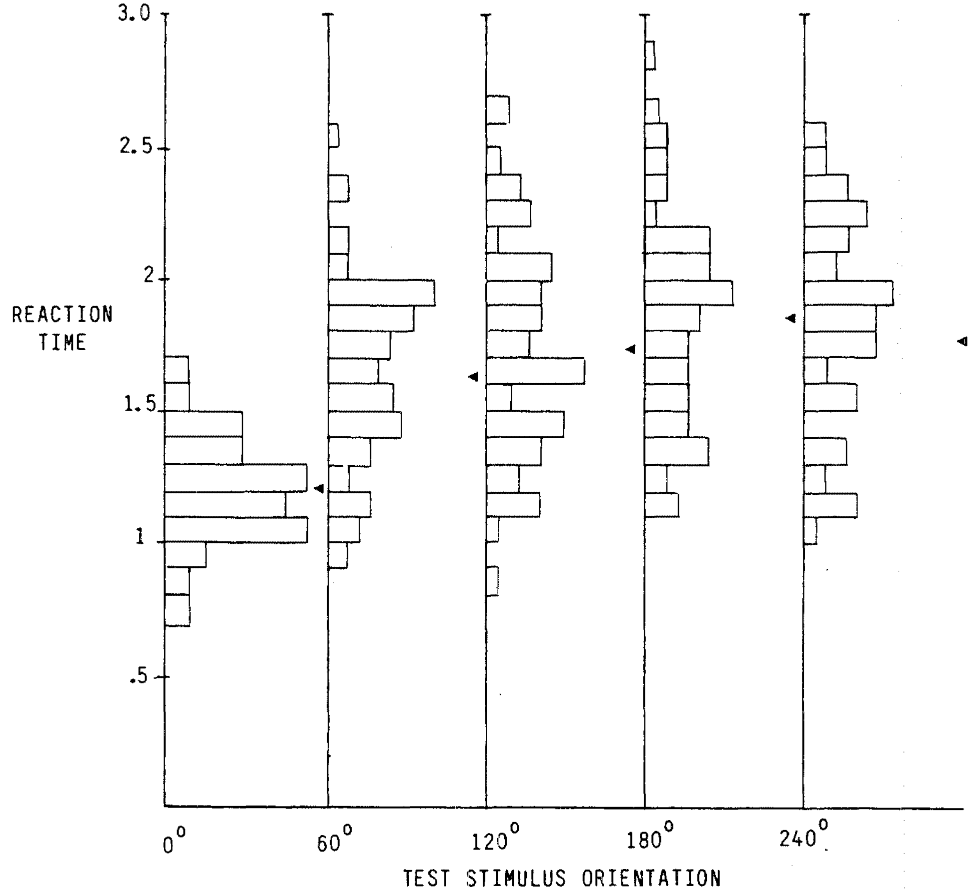
For non-match different test stimuli the only significant factors within the Imagery Groups x Memory Load x Test Stimulus Orientation x Subjects ANOVA were Memory Load, $F(3,18) = 27.8$, $p<.001$ and Orientation, $F(4,24) = 3.26$, $p<.025$. Trend analysis of the Memory Load main effect established that only the linear trend was significant, $F(1,18) = 80.56$, $p<.001$, and that this accounted for 96.6% of the factor variance. No increase in reaction time with orientation had been hypothesised and an examination of figure 4 (b) shows no systematic increase in reaction time with orientation, nor any other clear trend. Trend analysis confirmed this lack of any systematic pattern in the data.

Non-Match Mirror Image Test Stimuli

The overall Imagery Group x Memory Loads x Test Stimulus Orientation x Subjects ANOVA for non-match mirror image test stimuli revealed a significant Memory Load x Test Stimulus Orientation interaction, $F(12,72) = 2.44$, $p<.025$, as well as significant main effects for Memory Load, $F(3,18) = 3.17$, $p<.05$ and Test Stimulus Orientation, $F(4,24) = 4.65$, $p<.01$. Separate Imagery Groups x Test Stimulus Orientation x subjects ANOVAS at each memory load level revealed an orientation effect only at Memory Loads one, $F(4,24) = 3.15$, $p<.05$ and two $F(4,24) = 7.54$, $p<.001$.

Apparently any orientation effect declined as

FIGURE 6



Frequency graphs showing the distribution of data values at each test stimulus orientation increasing memory load increased the difficulty of the task. Examination of figure 4 (c) shows that the usually consistent pattern of a linear increase in reaction times with Memory Load does not apply at each orientation for non-match different test stimuli.

The presence of a three way interaction of Memory Load x Match/Mirror Image Test Stimuli x Test Stimulus Orientation, $F(12,72) = 2.67$, $p<.01$, in an Imagery Groups x Memory Load x Test Stimulus Orientation x Subjects ANOVA indicates the predicted simple situation of an extra processing stage after failure to detect a match to switch responses to detection of a non-match did not exist.

Summary: Reaction Time Results

From these discriminative reaction time data it can be seen that the landmark feature saliency manipulation was ineffective. Also no significant group differences were detected. As predicted, times for non-match different test stimuli did not show an increase with orientation. Also with matching test stimuli an orientation effect consistent with the hypothesised rotational transformation occurred. The detection of upright matches was carried out at the same speed as detection of test stimuli totally different from those memorized. The possibility exists that this occurred abnormally faster than match discrimination at other orientations. For both match and non-match different data a linear increase with memory load was found. Finally the results for the slowest process, detection of non-matching mirror image test stimuli, failed to replicate normal mental rotation experiment results. This data did not show a clear rotational transformation, any consistent increase with memory load or a distinct positive increment over match times. The implications of this will be taken up in the discussion section.

ERRORS

All analyses of error data which follow are based on errors made within the first presentation of an experimental condition (the first 160 trials) rather than total errors made, which includes repeated re-presentations of conditions on which errors were made. This was done firstly to avoid biasing results with data from a few conditions which proved uniquely difficult to individual subjects. Secondly it avoids the difficulties of replacing missing data from subject five's memory load four experimental session; where, as noted at the beginning of this Chapter, data was incomplete. The correlation of errors made on re-presentation of error trails with errors made within the first 160 trials at each memory load condition for each subject was highly significant ($r = .78$, $p<.001$, $n = 32$), indicating a continuous level of difficulty in re-presented trials. Comparable analyses to those following were performed on total error data and revealed the same overall trends.

Three situations within the experiment were classified as producing errors. Responses under 10 msec were classified as 'anticipations' of the appearance of the test stimuli. Response times over three seconds were deemed to be 'too slow' and rejected. And finally when a matching test stimulus was incorrectly identified as being different from those memorized or a non-matching test stimulus was identified as being the same as one of those memorized this was classified as being a 'wrong' error. Errors were predominantly 'wrong' response errors (88.43% of total errors made by all subjects), with a small number of 'too slow' responses (11.21%) and a minimal number of 'anticipations' or accidental triggerings of the reaction time keys before the test stimulus was presented (.36%). Thus the majority of error data was due to mistaken decisions as to whether the test stimulus matched a memory set stimulus. The rarity of accidental 'anticipation' errors precluded any statistical analysis of them. Analysis of 'too slow' errors was performed with an Imagery Groups x Memory Load x Type of Match x Test Stimulus Orientation x Subjects ANOVA but no significant effects were detected. The low rate for this type of error, together with the lack of significant relationship with any experimental factor shows subjects mainly coped with the demands of the task within the set time limit without excessive trading of speed of performance for accuracy.

Wrong decision errors were treated by an Imagery Groups x Memory Load x Type of Match x Test Stimulus Orientation x Subjects repeated measures ANOVA. Only the Memory Load, $F\ (3,18) = 6.24$, $p<.01$, Type of Match, $F\ (2,12) = 25.35$, $p\ .001$, and Orientation Factors $F\ (4,24) = 5.01$, $p<.01$, were significant. The groups effect was not significant and no interactions approached significance.

Trend analysis performed on data summed over all other factors but that in question indicated that error rates increased linearly with memory load, $F\ (1,21) = 19.82$ $p<.001$, and with orientation, $F\ (1,28) = 17.75$, $p<.001$.

Comparisons between the match, non-match mirror image and non-match different means indicated that decision errors for match and non-match mirror image conditions were significantly different, $F\ (1,7) = 7.67$, $p<.01$, and that fewer errors were made to non-match different test stimuli than to both matches, $F\ (1,7) = 39.13$, $p<.001$, and non-match mirror image test stimuli, $F\ (1,7) = 23.29$, $p<.001$. Values for this data can be seen in Table 2.

From this it is apparent that there is no difference between groups, that non-match mirror images are commonly misidentified as targets, matches are less commonly misperceived as non targets, and that non-match differents are rarely misclassified decision error rate increases with orientation and at much the same rate for each memory load. The effects of orientation and memory load appear similar across types of match.

RELATIONSHIP OF REACTION TIME AND ERROR RESULTS

These results mirror those of the reaction time data except for three major differences. Apparently error rates did increase over orientation with non-match different test stimuli even though reaction time showed no such increase. Even so, the error rate for this data was very low. For non-match mirror image test stimuli again there was an increase in decision errors with orientation without a corresponding clearcut increase in reaction times. Also, error rate data distinguishes between non-match mirror image and match data although reaction time data does not. These differences are explained if error data is seen as providing clues to the type of information being processed and reaction time data seen as detailing the flow of information processing.

TABLE 2

TYPE OF MATCH	MATCH					NON-MATCH:MIRROR IMAGE					NON-MATCH:DIFFERENT				
ORIENTATION	0	60	120	180	240	0	60	120	180	240	0	60	120	180	240
MEMORY LOAD 1	1.5	20.3	23.4	28.1	26.5	14	32.8	32.8	26.5	23.4	0	3.1	1.5	0	1.5
MEMORY LOAD 2	21.8	40.6	45.3	59.3	37.5	25	31.2	25	34.3	21.8	4.6	0	4.6	4.6	6.2
MEMORY LOAD 3	39	62.5	54.6	59.3	71.8	23.4	25	29.6	42.1	32.8	4.6	7.8	4.6	6.2	1.5
MEMORY LOAD 4	23.4	40.6	57.8	60.9	57.8	43.7	32.8	46.8	45.3	46.8	7.8	9.3	4.6	12.5	14

Table showing distribution of wrong response errors. All values are percentages of total presentations of that condition pooled over subjects and stimuli

CHAPTER IV

DISCUSSION

STIMULUS FACTORS

Although an overall significant difference between stimulus memorization times occurred no distinct groups of stimuli were apparent. Similarly no systematic differences occurred in stimulus encoding time, transformation rate, or error rate. This contrasts with the reliable large stimulus differences in both slope and intercept found in Hochberg and Gellman (1977). It is impossible to reach many firm conclusions except with regard to the current implementation of Hochberg and Gellman's theory of stimulus feature saliency being critical to mental rotation. Although salient features are defined as being "...cues to location and orientation that are unique and visible from a distance..." (Hochberg and Gellman, 1977, p23) this apparently cannot be operationalized by varying the size of or presence of a major perturbed point in one side of an Attneave random shape. If effective 'feature saliency' manipulation requires alterations to such factors as number of points perturbed or overall shape of the stimulus then the utility of the concept becomes doubtful. It becomes a synonym of complexity as used by other researchers (eg. Attneave, 1957; Cooper, 1975). Thus the possibility exists that Hochberg and Gellman only demonstrated a complexity effect at an unknown stage within a mental rotation task.

It is not apparent what did contribute to the differences in stimuli in the present experiment if 'feature saliency' was not effectively manipulated and 'complexity' (defined as number of points perturbed) was equal. The potential of the present experimental design for deductive isolation of both processing stages and representation type was not exploited with no clear stimulus differences at any processing stage being found.

IMAGERY GROUPS FACTOR

The lack of any significant difference between imagery groups on all variables (memorization times, error rates and discriminative reaction times) is somewhat surprising. It is possible that this was due to selecting the groups on the basis of an introspective self-report imagery questionnaire. Historically this type of instrument has produced low correlations with actual performance measures of imagery and have been strongly criticised because of a lack of objectivity in measurement. (eg. Richardson, 1980, p118-142; Kaufman, 1981). However the Vividness of Visual Imagery Questionnaire is the most recent development in a family of tests derived from Galton's 'breakfast table' procedure and has been shown to have high internal consistency and test re-test reliability, to have only a single dimension on factor analysis and to correlate with some objective performance measures of imagery ability (Marks 1972; 1973; 1977; McKelvie & Gingras, 1974; Gur & Hilgard 1975; White, Sheehan & Ashton, 1977). It may be that sex differences among subjects confounded the imagery factor. Small sample size and unbalanced numbers made this impossible to investigate statistically. Another possibility is that the sample size was too small for clear detection of group differences. Also, it may be possible for subjects to solve the task by spatially manipulating the stimuli at some deep abstract code level without recourse to phenomenal images, in which case vividness of attentionally controlled imagery (as measured by the V.V.I.Q.) is irrelevant.

However an experimental precedent to the present results exists in the work of Ashton, McFarland, Walsh and White, 1978. Their experiment was a mental rotation task using a rotated hand recognition paradigm (from Cooper & Shepard, 1975). Their groups were also chosen on the basis of a self-report questionnaire (a modification of the visual modality section of Bett's 1909 Questionnaire Upon Mental Imagery). As with this experiment, subjects without explicit instructions to use an imagery strategy were undifferentiated. However on the same task an imagery group difference was found when instructions to use an imagery strategy were given. Thus the present results may well be a true finding not contaminated by uncontrolled factors. The lack of any imagery group differences makes it impossible to speculate whether mental imagery (as opposed to other cognitive abilities) was more functionally involved in some stages of the information processing sequence than in others. A more positive conclusion is not possible.

MEMORY SEARCH PROCESS

Memorization time can be interpreted as a measure of encoding duration or information pickup. The linear increase in time to memorize a stimulus set with increasing stimulus set size can be interpreted as indicating that all stimuli were initially encoded to at least an equal degree regardless of the number being presented. Thus any increase in discriminative reaction times with increasing memory load can be interpreted as evidence for a memory search phase in processing rather than being due merely to differences in the strength or clarity of the mental representation being accessed. Analysis of average reaction times with increasing memory load showed this to be the case. The only deviation from the clearly additive effect of the memory load manipulation involves the non-match mirror image response situations. That subjects without foreknowledge of the type of match only performed a memory search in the non-match different and match conditions seems unlikely. A more probable interpretation is that some factors imposed an upper limit on discriminative response times which had a stronger effect on the longer non-match mirror image decision times than the memory load factor did. This will be considered in detail below in the discussion on the latter processing stages.

The exact nature of the memory search process is not ascertainable from the present date. It may have been a serial check of each stored item, a parallel processing of all items with greater information being considered, or some more complex combination of processes. Allegiance to the principal of parsimony would lead to a theorized serial search process but this may indicate neglect of the true complexity of the human brain due to too close a following of a digital computer metaphor of mind. One implication of assuming a serial search process is that data from higher memory load conditions would contain greater variance. This is because serial search logically produces longer times with more search only on average. Unless the search process is exhaustive it will terminate once the desired item is located. Randomising the position of target stimuli within the non linear memory display only minimizes this effect. This may go towards explaining the lack of differentiation in the data between the close match and non-match mirror image conditions which is especially evident at higher memory loads.

Hypthesising use of an exhaustive search process eliminates potential problems of greater data variance with higher memory loads. However it is not possible to test for such processing details within the experimental design. This would however appear to be a sub-optimal strategy for subjects to adopt.

The exact location of memory search within the information processing flow has to be deduced from the experimental situation. A comparison stage is often assumed to occur after mental representations have been transformed to match in orientation to check for the occurrence of template-like matching, eg. Cooper & Shepard, 1973, p135. Furthermore the manipulation of memory load has been theorized to influence a comparison stage. (Seymour, 1979, p63). However to place the memory search stage here implies that memory representations are scanned after identification and rotation transformation stages. This goes against the evidence for the efficiency of the identification stage.

It is more logical to place the memory search stage before the identification stage. This is in line with its additive effect on the early information processing stages of identification and rotational transformation as reflected in the non-match different and match response situation data.

EARLY STIMULUS IDENTIFICATION STAGE

There were consistently rapid response times unaffected by test stimulus orientation and low error rates for non-match different responses. With upright test stimuli there was no difference in response times between non-match different and match responses. Response times to match responses however increased with test stimulus orientation.

This is strong evidence for an initial information processing stage giving some knowledge of test stimulus identity independent of its orientation. This level of analysis may occur before a 'mental rotation' stage or be concurrent with it but operating at a faster rate. The information available during this stage is sufficient to allow rapid discrimination, regardless of orientation, in all non-match situations involving test stimuli different from those encoded during memorization. At this stage there is also sufficient information for rapid detection of matches between test stimuli and memorized representations as long as no difference in orientation exists. However further processing is required for misoriented matching test stimuli as is shown by the significant difference between the rapid non-match different and slower match responses at all orientations away from upright.

These results replicate and extend some of the findings of Shinar and Owen, 1973. Their experiment used a similar additive factors paradigm manipulating memory load and test stimulus orientation but only requiring discrimination between matching and non-matching different stimuli. They produced similar results with test stimulus orientation only effecting the slower match responses and no difference occurring between match and non-match responses with upright stimuli (Shinar and Owen, 1973, p151). These effects were much smaller and only occurred during initial practice sessions with a memory load of one stimulus. With increased practice and memory load the orientation effect on match responses became quicker than non-match responses. This change was seen as due to the adoption of a recoding strategy (use of verbal labels for stimuli based on rotationally invariant features) and a self-terminating search strategy (non-match responses being made only after all testing for a match had failed). All speculation about the locus of rotation effects was based on the data gathered after the practice session which was admitted to reflect a different process from that found in mental rotation experiments. The results of their practice session were not accounted for.

Further data supporting the present results has been gathered in several experiments with paradigms requiring identification of a test stimulus rather than the usual discrimination of differences between stimuli or verification of similarities between stimuli. They have shown orientation to have no effect or effects differing vastly from the additive 'mental rotation' effect. Any orientation differences occurring decline with practice. Tasks have included identification of specific alphanumeric characters; detection of the presence or absence of a target character (Corballis, Zbrodoff, Shetzer & Butler, 1978); and classification as either a letter or a digit (Corballis & Nagourney, 1978). The generality of this evidence has been extended to novel non-alphanumeric stimuli and been shown to be unaffected by stimulus familiarity or the size of the known stimulus pool (Eley, 1982). Comparisons with times in tasks requiring detection of a target orientation (Corballis et al, 1978) or mirror image discrimination (Eley, 1978) have lead to the conclusion that this identification stage occurs before any transformation stage. Thus these results show that the information used during an identification paradigm task is extracted independently of stimulus orientation. This has been extended to the theory that the identification process involves "...extraction of critical features encoded invariant to ...orientation" (Eley, 1982, p25).

To sum up, the present experiment provided strong evidence for the existence of an early stimulus identification process in a mental rotation task, replicating the information processing strategy used only transiently by the subjects of Shinar and Owen. The within subject design combining types of match provided evidence that this process precedes rotational transformation; a processing sequence previously deduced from the weaker evidence of the between groups and tasks designs used in the identification paradigm experiments. At this stage decisions were based on orientation independent information sufficient to accurately identify the occurrence of totally different test stimuli. However matching test stimuli could only be identified if they were at the same orientation as memorized stimuli. This suggests the mental representations used were composed of some critical stimulus features but not all the essential spatial structure of their corresponding external referents.

ROTATIONAL TRANSFORMATIONS (AND REPRESENTATION ELABORATIONS?)

Only for the match response condition was there clear cut evidence for the 'mental rotation' effect of increasing discriminative reaction time with test stimulus misorientation from the standard orientation of the memorized stimuli. This occurred at all memory loads. Non-match different responses never showed the 'mental rotation' pattern. An early identification stage of processing was hypothesized to account for this. Non-match mirror image responses showed significant orientation effects only up to a memory load of two. This was vaguely like the mental rotation pattern but not clearly an additive effect over increasing orientation. Consideration of theoretical explanations for this data occur in the next sub-section.

It appears that after an initial memory search and identification processes, rotational transformations occur which provide information sufficient to detect matches between test stimuli and memorized stimuli. This is the theorized 'mental rotation' stage.

The possibility exists that further information processing occurs after the identification process but before the rotational transformation process. Weak evidence for this is the faster reaction times for upright stimuli than that value predicted by linear extension of the regression line for match responses at other test stimulus orientations. At this stage additional processing could elaborate the representations used during the identification process to allow the extraction of further information by rotational transformation. The processing within this hypothesized stage could be either propositional elaboration or generation of a mental image.

Normally the assumption is made that the representation of the test stimulus is the one transformed during 'mental rotation'. Evidence supporting this comes from the pattern of eye movement made while viewing the test stimulus in a successive presentation paradigm (Just & Carpenter, 1978). The assumption that the test stimulus representation is transformation appears more justified in paradigms involving presentation of a test item which is a misoriented version of a well known stimulus such as an alphanumeric character and requiring discrimination of whether it is normal or mirrored. Here highly overlearned upright cannonical representations can be assumed to exist against which the test stimulus must be compared. Less certainty exists within the present paradigm as to whether the representation of the visually presented stimulus or that of the memorized stimulus is transformed. Both operations could be difficult to perform. There is the possibility that transformation of the memorized stimulus will deform it leaving inadequate information for processing. And the flow of information from the visually presented stimulus may interfere with operations on its representation. Introspective reports of subjects indicated a subjective feeling of the test stimulus being transformed. However the experimental design does not provide data sufficient to resolve the issue.

LATE DECISION PROCESSING

The data from the non-match mirror image response condition is the most difficult to account for. Typically mental rotation experiments have shown the regression line of reaction time against stimulus misorientation from the upright condition to have the same positive slope as the match condition but a higher intercept. This has been interpreted as evidence for an initial self-terminating search for a positive response situation by rotational transformation and template-like matching processes. For mirror image stimuli this was followed by additional operations to switch motor control to the negative response and possibly additional transformations to verify the mismatch (eg. Cooper & Shepard, 1973, p163-167). However in the present experiment the orientation differences in the mirror image condition are only evident at low memory loads, as are clear difference between the match and mirror conditions.

One response to these results would be to dismiss them as artifactual. The data may not represent positive detection of mismatches of test stimuli and memorized stimuli but instead include a large proportion of guesses. This would give a wide distribution of reaction times around the 'true' values and reduce the statistical power of tests of differences between mean values. This interpretation is supported by the high average error rate for the non-match mirror image conditions, which reaches chance levels at times.

If one accepts the pattern of results as valid and makes only serial additive factors assumptions then the results do have an explanation. It is that subjects performed additional mental operations (transformations?) after the initial rotational transformation (evident with matching test stimuli) had failed to produce a verified match but continued to do so only until a maximum time criterion was reached. After this time, if no match had been identified, the 'different' response was made. Evidence for these additional operations is the lack of a drop in reaction time for mirror responses with upright test stimuli. In this case there was a rapid negative response to non-matching different stimuli and an equally rapid positive response to matching stimuli (the positive response being below that predicted by a linear extension of match response time at all other test stimulus orientations). In contrast to these rapid responses there is a long delay before the negative response to upright mirror image stimuli. Further processing than merely readying and executing the negative response must have filled this time period. This would account for the lack of a test stimulus orientation effect for the non-matching mirror image response condition and lack of an increase in time for these decisions with higher memory loads once an upper time limit had been reached. This hypothesized it-must-be-a-non-matching-mirror-image-if-this-much-time-has-passed-without-a-match-being-found strategy may have been an artifact caused by the need to response within the upper limit of three seconds which was placed on the discriminative process, or it may have been due to information processing limitations making it optimal to guess after a certain time had passed.

If the memory storage mechanisms used by subjects within this experiment act similar to normal short-term memory mechanisms then limitations in storage capacity, mental resource available for other processing and fading of memory details with time can all be invoked theoretically. Merely holding more information could result in a loss or confusion of details in the mental representations of the to-be-remembered stimuli. The greater average search time with higher memory loads could result in degraded information being available for transformation and decision processes. This would account for a decrease in distinction between match and mirror image test stimuli with memory load and the hypothesized adoption of a time cut off strategy.

ERROR DATA

Error rates in this experiment were extremely high relative to typical mental rotation experiments. Normally reported error rates are less than 10% of total trials, mainly because of the use of highly practiced subjects and large numbers of trials eg. 12,800 trials in Shepard and Metzler, 1971. Rarely are sufficient errors made to provide a pool of analyzable data, nor are significant relationships found if analysis is attempted. In fact, reaction time data from subjects with a high error rate is often excluded from further analysis (eg. Pylyshyn, 1979). The most common use of error data is to demonstrate that variations in speed-accuracy trade-off between conditions has not made it impossible to interpret reaction time data (Pachella, 1974). The only comparable error rate to that found in this experiment is reported by Cooper and Podgorny, 1976. Their subjects produced 34.78% errors in a condition requiring discrimination of distractors with only one point perturbed after a preparatory mental rotation of a target Attneave shape.

Decision errors and reaction times increased with memory load and test stimulus orientation away from the upright. That is errors and reaction time were positively correlated. From the kind of speed-accuracy trade-off relation posited by Pachella (1974) this suggests that reaction times in the more demanding memory and orientation conditions are likely to be under-estimations.

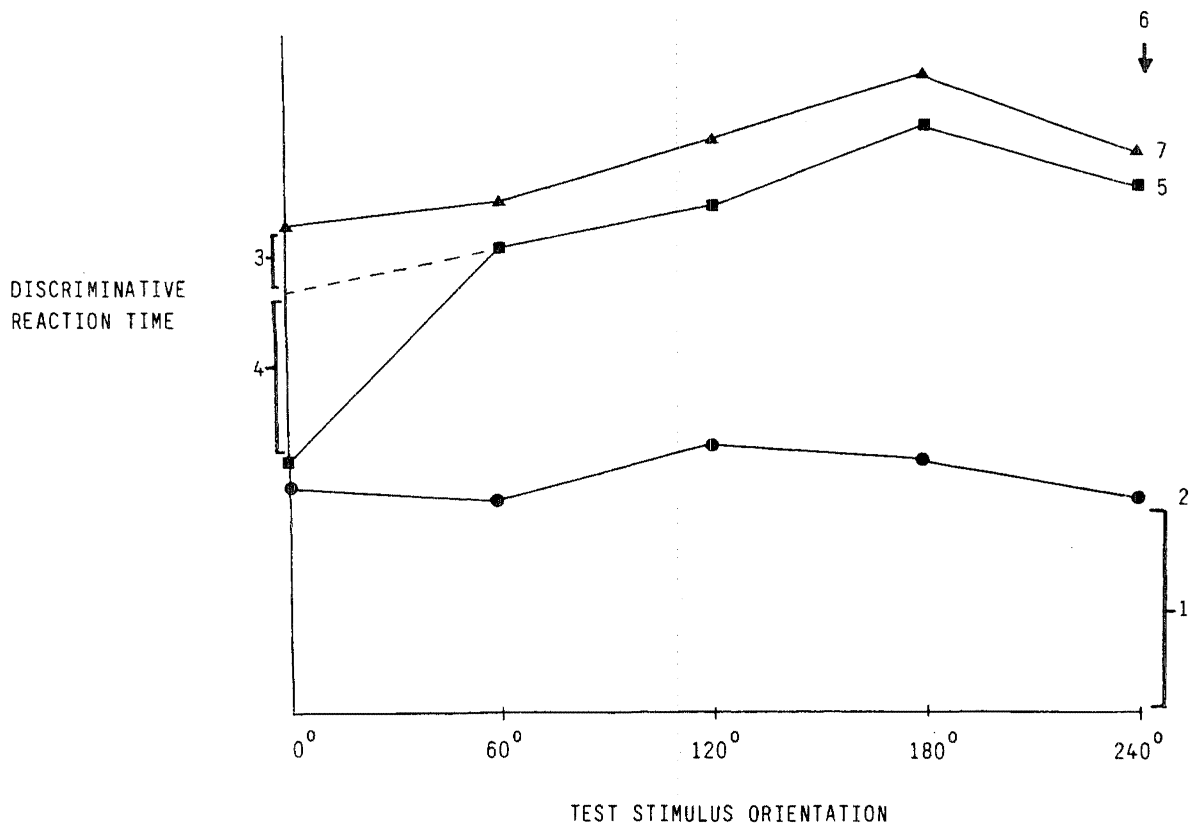
CHAPTER V

CONCLUSIONS

A summarization of details of the information processing sequence hypothesised in the discussion section can be seen in figure 7. This is based on times averaged over memory loads, stimuli, and subjects and shows diagramatically the relationship between evidence for each processing stage and actual discriminative reaction times.

It has been argued that the experiment provided evidence for the existence of a rotational transformation stage (used to determine the existence of matching test stimuli) which was separated from an encoding and memory search stage and from stimulus identification processes. This more firmly establishes the results produced by Shinar and Owen, 1973. The experiment also replicated studies which placed the identification process before rotational transformation. Additionally tentative evidence was found for a recoding stage following stimulus identification. The data for non-matching mirror image test stimuli highlights the effects of high processing demands on mental imagery, an issue not dealt with by mental rotation experiments before except speculatively in Roldan and Philips, 1980. The two negative results raised interesting issues: firstly there are doubts about the utility of the concept 'landmark feature saliency' as distinct from a more gestalt term like complexity. The determining feature in the stimulus results appears to be "...the complexity of the task as a whole rather than the complexity of the

FIGURE 7



KEY

■ - Matching Test Stimuli
▲ - Non-matching Mirror Image Test Stimuli
● - Non-matching Different Test Stimuli

1 - Memory Search

2 - Stimulus Identification
(Based on rotationally invariant features)

3 - Additional transformations at 0° until a time limit is exceeded then execution of a 'different' response

4 - Recoding

5 - Rotational Transformations, as evidenced by ....

6 - Back rotation at 240°

7 - Time limited response unaffected by memory load

A speculative model of the information processing sequence during the task stimulus alone". (Pylyshyn, 1979, p26). Secondly the lack of any difference between the imagery groups also raises doubts about the usefulness of the V.V.I.Q. and highlights the need for careful definition of which mental abilities are tapped by the mental rotation task. All the preceding results are interesting additions to the body of knowledge about the mental rotation phenomena and the two negative results together with the effect of demand on imagery performance are issues worthy of further investigation.

However the issue of most interest is the metatheoretical argument that there is an unavoidable indeterminacy between evidence for the nature of imagery representation and evidence for mental imagery processes. The intention had been to avoid previous methodological weaknesses by not using a simultaneous presentation paradigm (unable to delimit separate processing stages) and to use stimuli which tested claims of a difference in rotational rate (indicative of the use of propositionally coded information). The inclusion of two extreme imagery groups was meant to further increase the power of the experiment to differentiate representation and process. Whatever positive conclusions can be made on the basis of experimental results, a serious challenge to the indeterminacy claim is not among them. This appears however to be due to a number of unforeseen methodological weaknesses rather than a basic fault in the experimental design and intentions.

Firstly the failure of the imagery group manipulation resulted in a diverse subject pool of a wide range of ability which contributed variability within data. This may well have reduced the probability of detecting mean differences on other factors and clouded other issues. The high error rates due to the difficulty of the task were also unforeseen and reduced the interpretability of the data. The relatively low number of measurements made per treatment condition aggrievated this problem. The three second limit put on discriminative responses raises objections that the ceiling effect with non-matching mirror image test stimuli could have been artifactual. Finally the failure of the stimulus manipulation reduced much of the power of the design as it meant deductions could only be made about processing stages and not details of the representation used. The expected result had been for there to be either: a clearcut difference in memorization times and identification times but not in rotation rates, or for there to be a difference at both encoding and transformation stages.

More interpretable results seem possible with a replication study following the same basic paradigm. This study would however include a more homogenous control group of subjects, of moderate imagery ability, as well as the two extreme samples. Objective ability tests of image formation and manipulation would be used to screen subjects. An attempt would be made to reduce error rate by more stringent training of subjects and use of a 'mixed set' procedure including all memory loads within one experimental session so as to eliminate the need for a continuous high resource demanding level of performance. A greater number of replications of experimental conditions could be achieved by reducing the number of orientations for test stimuli. Evidence for the rotational trajectory of transformations would be gathered by testing occasionally at intermediate orientations. Finally a more conventional choice would be made for the stimulus factor. The obvious option is to vary the number of points on Attneave polygons ('complexity'?) and Anderson's suggestion of using test stimuli with only one angle altered by an equal amount for all stimuli. Alternatively there is promise in Yuille and Steiger's 1982 use of Shepard-type twisted torsi with additional non-informative features added. (This could again test the landmark feature saliency concept).

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APPENDIX 1

MEMORY LOAD = 1

TYPE OF MATCH	MATCH				NON-MATCH:MIRROR IMAGE				NON-MATCH:DIFFERENT			
ORIENTATION	0	60	180	240	0	60	180	240	0	60	180	240
STIMULI	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8
LOW IMAGERY GROUP												
HIGH IMAGERY GROUP												

MEMORY LOAD = 2

TYPE OF MATCH	MATCH				NON-MATCH:MIRROR IMAGE				NON-MATCH:DIFFERENT			
ORIENTATION	0	60	180	240	0	60	180	240	0	60	180	240
STIMULI	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8
LOW IMAGERY GROUP												
HIGH IMAGERY GROUP												

MEMORY LOAD = 3

TYPE OF MATCH	MATCH				NON-MATCH:MIRROR IMAGE				NON-MATCH:DIFFERENT			
ORIENTATION	0	60	180	240	0	60	180	240	0	60	180	240
STIMULI	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8
LOW IMAGERY GROUP												
HIGH IMAGERY GROUP												

MEMORY LOAD = 4

TYPE OF MATCH	MATCH				NON-MATCH:MIRROR IMAGE				NON-MATCH:DIFFERENT			
ORIENTATION	0	60	180	240	0	60	180	240	0	60	180	240
STIMULI	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8
LOW IMAGERY GROUP												
HIGH IMAGERY GROUP												

A diagramatic representation of the experimental design

APPENDIX 2

DOCUMENTATION OF EXPERIMENTAL CONTROL PROGRAM

PROGRAM FLOW

10-40	Title
60-90	Establish arrays
100-110	Load Assembly Language Timing Routine
120-150	Load Stimulus Plotting Data
160-270	Establish if this is a practice or experimental session and initialize accordingly
280-360	Read in stimuli to be plotted on each trial
361-364	Establish subject code for the session
370-540	Make sure reaction time keys are in the right place
550	Display fixation cross
560-570	Establish correct response for this trial
630-730	Ready all plotting co-ordinates for this trial (decoding from alphanumerics and scaling to size)
740-910	Reposition all memory set stimuli correctly
920	Initialize timing routine
930-950	Auditory warning signal
960	Delay
970-1020	Plot memory set
1030	Start timer (program 'hangs' until a response is made)
1040	Determine memorization time
1050	Reinitialize timer
1060-1070	Plot test stimulus
1080	Start timer (program hangs until a response is made)

1090	Plot fixation cross
1100	Determine reaction time
1110	Determine response
1130-1170	If an error is made give appropriate error message, note the trial for latter re-presentation and go to the next trial
1171-1250	If no error is made record memorization time and reaction time in appropriate place for the type of match, stimulus and test orientation involved
1260-1340	Either move on to the next trial or: If finished move to re-present error trials or: If finished all error trials move to finish message
1350	Finish message to subject
1360-1440	Data stored to disk and program ends
1450-1500	Sub-routine: records trial where an error occurred along with memorization and reaction time
1510-1519	Sub-routine: Plots fixation cross and feedback line
1520-1580	Sub-routine: Too slow error message
1590-1650	Sub-routine: Wrong response error message
1660-1720	Sub-routine: Anticipation error message

ARRAYS USED

Z$ (80)	Stores alphanumerically centred co-ordinates for all stimuli at each orientation and their mirror images (8x5x2)	
X% (160,5)	Stores details for each trial:	
	X% (n,0)	Test Stimulus
	X% (n,1)	Memory Set Stimulus #1
	X% (n,2)	Memory Set Stimulus #2
	X% (n,3)	Memory Set Stimulus #3
	X% (n,4)	Memory Set Stimulus #3
	X% (n,5)	Correct Response
A% (44)	Stores X co-ordinates for plotting on each trial	
B% (44)	Stores Y co-ordinates for plotting on each trial	
S% (80)	Stores all 'same' response data	
D% (80)	Stores all 'different' response data	
M% (160)	Stores memorization times	
E% (250,2)	Stores details of error trials:	
	E% (n,Ø)	Memorization time in error trials
	E% (n,1)	Reaction times in error trials
	E% (n,2)	Trial on which an error was made

IMPORTANT VARIABLES

AGAIN	A flag for when to re-present trials on which errors occurred
FINISH	Total number of trials to end of session
K1	Left response key's ASCI code
K2	Right response key's ASCI code
KE	Correct response for a trial
MEMTYM	Memorization time for a trial
MS	Memory load for a session
RDO	Next empty space to store error data
RS	ASCI value of reaction time key pressed
RE	Reaction Time
TURN	Number of current trial

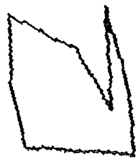
```
980  ON MS GOTO 1020,1010,1000
990  HPLOT A%(36),B%(36) TO A%(37
     ),B%(37) TO A%(38),B%(38) TO
     A%(39),B%(39) TO A%(40),B%(4
     0) TO A%(41),B%(41) TO A%(42
     ),B%(42) TO A%(43),B%(43) TO
     A%(44),B%(44)
1000  HPLOT A%(27),B%(27) TO A%(2
     8),B%(28) TO A%(29),B%(29) TO
     A%(30),B%(30) TO A%(31),B%(3
     1) TO A%(32),B%(32) TO A%(33
     ),B%(33) TO A%(34),B%(34) TO
     A%(35),B%(35)
1010  HPLOT A%(18),B%(18) TO A%(1
     9),B%(19) TO A%(20),B%(20) TO
     A%(21),B%(21) TO A%(22),B%(2
     2) TO A%(23),B%(23) TO A%(24
     ),B%(24) TO A%(25),B%(25) TO
     A%(26),B%(26)
1020  HPLOT A%(9),B%(9) TO A%(10)
     ,B%(10) TO A%(11),B%(11) TO
     A%(12),B%(12) TO A%(13),B%(1
     3) TO A%(14),B%(14) TO A%(15
     ),B%(15) TO A%(16),B%(16) TO
     A%(17),B%(17)
1030  CALL 768
1040 MEMTYM =  PEEK (812) * 256 +
      PEEK (811)
1050  POKE 6,0: POKE 811,0: POKE
     812,0: POKE  - 16368,0
1060  HGR2
1070  HPLOT A%(0),B%(0) TO A%(1),
     B%(1) TO A%(2),B%(2) TO A%(3
     ),B%(3) TO A%(4),B%(4) TO A%
     (5),B%(5) TO A%(6),B%(6) TO
     A%(7),B%(7) TO A%(8),B%(8)
1080  CALL 768
1090  GOSUB 1510
1100 RS =  PEEK ( - 16384)
1110 RE =  PEEK (812) * 256 +  PEEK
     (811)
1120 KT = 0
1130  IF RE > 4000 THEN  GOSUB 15
     20
1140  IF RS <  > KE THEN  GOSUB 1
     590
1150  IF RE < 10 THEN  GOSUB 1660

1160  IF KT = 1 THEN  GOSUB 1450
1170  IF KT = 1 THEN 1260
1171 II = 0: FOR J = 1 TO MS: IF
     X%(TURN,J) > 40 THEN II = II
      + 1: NEXT J
1172  IF II = 0 THEN 1190
1173  IF X%(TURN,5) = 0 THEN B =
     X%(TURN,0) - 40
1174  IF X%(TURN,5) = 1 AND X%(TU
     RN,0) < 41 THEN B = X%(TURN,
     0) + 40
1175  IF X%(TURN,5) = 1 AND X%(TU
     RN,0) > 40 THEN B = X%(TURN,
     0) - 40
1176  GOTO 1200
1190 B = X%(TURN,0)
1200  IF X%(TURN,5) = 0 THEN 1230

1210 M%(B + 80) = MEMTYM
1220 D%(B) = RE: GOTO 1260
1230  IF S%(B) > 0 THEN B = B + 4
     0
1240 S%(B) = RE
1250 M%(B) = MEMTYM
1260  IF AGAIN = 1 THEN 1320
1270 TURN = TURN + 1
1280  IF TURN <  = FINISH THEN 56
     0
```

```
10  HOME : PRINT "       ";: FLASH
     : PRINT "ROTATED SHAPES EXPE
     RIMENT": NORMAL
20  VTAB 8
30  PRINT "PLEASE WAIT WHILE"
40  PRINT "EXPERIMENTAL DETAILS A
     RE LOADING"
60  DIM Z$(80),X%(160,5)
70  DIM A%(44): DIM B%(44)
80  DIM S%(80): DIM D%(80)
90  DIM M%(160): DIM E%(250,2)
100 D$ =  CHR$ (4)
110  PRINT D$;"BLOAD TIMERS"
120  PRINT D$;"OPEN SHAPES"
130  PRINT D$;"READ SHAPES"
140  FOR C1 = 1 TO 80: INPUT Z$(C
     1): NEXT C1
150  PRINT D$;"CLOSE SHAPES"
160  TEXT : HOME
170  PRINT "  ENTER MSET VALUE (0
     =END)"
220  GET M$
230 MS =  VAL (M$):M$ = "ST" + M$

240  IF MS = 0 THEN 1440
250 L1 = 1:FINISH = 160:TURN = 1:
     RDO = 1:AGAIN = 0:V2 = 5:ZZ =
     0
260  IF MS < 5 THEN 280
270 FINISH = 16:V2 = 2:ZZ = 1:MS =
     1
280 D$ =  CHR$ (4)
290  PRINT D$;"OPEN";M$
300  PRINT D$;"READ";M$
310  FOR J = 1 TO FINISH
320  FOR K = 0 TO V2: INPUT X%(J,
     K): NEXT K
330  NEXT J
340  IF ZZ <  > 1 THEN 360
350  FOR J = 1 TO 16:X%(J,5) = X%
     (J,2): NEXT J
360  PRINT D$;"CLOSE";M$
361  PRINT "ENTER SUBJECT CODE": INPUT
     S$
362  VTAB 5
363  PRINT "SUBJECT CODE=";S$: PRINT
     "OK?(Y/N)"
364  GET A$: IF A$ = "N" THEN 361

365 S$ = "S" + S$
370  HOME
380  FLASH : PRINT "KEY SETUP ROU
     TINE": PRINT : NORMAL : PRINT

390  PRINT "IS THE RIGHT KEY"
400  PRINT "FOR POSITIVE RESPONSE
     S?(Y/N)"
410  GET A$
420  IF A$ = "N" THEN  GOTO 440
430 K1 = 46:K2 = 45: GOTO 460
440 K1 = 45:K2 = 46
450  PRINT : PRINT : PRINT
460  PRINT "HIT WHAT IS MEANT TO
     BE THE POSITIVE KEY"
470  GET A$
480 A =  ASC (A$)
490  IF A = K1 THEN  PRINT "KEYS
     O.K."
500  IF A = K2 THEN  PRINT "KEYS
     ARE WRONG WAY AROUND,SWAP TH
     EM OVER"
510  IF A = K2 THEN 460
520  FOR J = 1 TO 1000: NEXT J: HOME

540  HOME : PRINT "PUSH ANY KEY T
     O START": GET A$
550  GOSUB 1510
```

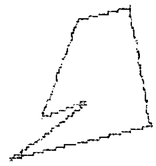
```
560  IF X%(TURN,5) = 1 THEN KE =
     K2
570  IF X%(TURN,5) = 0 THEN KE =
     K1
630 P = 0:Q = 8
640  FOR C1 = 0 TO MS
650 A = X%(TURN,C1)
660 Z$ = Z$(A)
670 X = 1: FOR C2 = P TO Q
680 Z1$ =  MID$ (Z$,X,3):A%(C2) =
      VAL (Z1$):X = X + 3
690 Z1$ =  MID$ (Z$,X,3):B%(C2) =
      VAL (Z1$):X = X + 3: NEXT C
     2
700  FOR C3 = P TO Q:A%(C3) = A%(
     C3) * .81:B%(C3) = B%(C3) *
     .81: NEXT C3
710 D =  FRE (0)
720 P = P + 9:Q = Q + 9
730  NEXT C1
740  FOR L = 0 TO 8:A%(L) = A%(L)
      + 27:B%(L) = B%(L) + 32: NEXT
     L
750  ON MS GOSUB 860,840,810,770
760  GOTO 920
770  FOR L = 9 TO 17:A%(L) = A%(L
     ) - 38:B%(L) = B%(L) - 12: NEXT
     L
780  FOR L = 18 TO 26:A%(L) = A%(
     L) - 38:B%(L) = B%(L) + 76: NEXT
     L
790  FOR L = 27 TO 35:A%(L) = A%(
     L) + 92:B%(L) = B%(L) - 12: NEXT
     L
800  FOR L = 36 TO 44:A%(L) = A%(
     L) + 92:B%(L) = B%(L) + 76: NEXT
     L: RETURN
810  FOR L = 9 TO 17:A%(L) = A%(L
     ) + 27:B%(L) = B%(L) - 12: NEXT
     L
820  FOR L = 18 TO 26:A%(L) = A%(
     L) - 39:B%(L) = B%(L) + 76: NEXT
     L
830  FOR L = 27 TO 35:A%(L) = A%(
     L) + 92:B%(L) = B%(L) + 76: NEXT
     L: RETURN
840  FOR L = 9 TO 17:A%(L) = A%(L
     ) - 38:B%(L) = B%(L) + 32: NEXT
     L
850  FOR L = 18 TO 26:A%(L) = A%(
     L) + 92:B%(L) = B%(L) + 32: NEXT
     L: RETURN
860 D = ( RND (1) * 4) + 1
870  ON D GOTO 880,890,900,910
880  FOR L = 9 TO 17:A%(L) = A%(L
     ) - 38:B%(L) = B%(L) - 12: NEXT
     L: RETURN
890  FOR L = 9 TO 17:A%(L) = A%(L
     ) - 38:B%(L) = B%(L) + 76: NEXT
     L: RETURN
900  FOR L = 9 TO 17:A%(L) = A%(L
     ) + 92:B%(L) = B%(L) - 12: NEXT
     L: RETURN
910  FOR L = 9 TO 17:A%(L) = A%(L
     ) + 92:B%(L) = B%(L) + 76: NEXT
     L: RETURN
920  POKE 6,0: POKE 811,0: POKE 8
     12,0: POKE  - 16368,0
930  FOR C1 = 1 TO 10
940 SOUND =  PEEK ( - 16336) -  PEEK
     ( - 16336) +  PEEK ( - 16336
     ) +  PEEK ( - 16336) -  PEEK
     ( - 16336) +  PEEK ( - 16336
     )
950  NEXT C1
960  FOR C2 = 1 TO 250: NEXT C2
970  HGR2
```

```
1290 AGAIN = 1
1310  IF RDO = 1 THEN 1345
1320 TURN = E%(L1,2)
1330 L1 = L1 + 1
1340  IF L1 <  = RDO THEN 560
1345  IF ZZ = 1 THEN 160
1350  TEXT : HOME : PRINT "RELAX,
     RUN OVER"
1360 D$ =  CHR$ (4)
1370  PRINT D$;"OPEN";S$
1380  PRINT D$;"WRITE";S$
1390  FOR C1 = 1 TO 80: PRINT S%(
     C1): NEXT C1
1400  FOR C2 = 1 TO 80: PRINT D%(
     C2): NEXT C2
1410  FOR C3 = 1 TO 160: PRINT M%
     (C3): NEXT C3
1420  FOR C4 = 1 TO 250: PRINT E%
     (C4,1): PRINT E%(C4,2): PRINT
     E%(C4,0): NEXT C4
1430  PRINT D$;"CLOSE";S$
1440  TEXT : HOME : FLASH : PRINT
     "FINISHED": NORMAL : END
1450  REM
1460 E%(RDO,1) = RE
1470 E%(RDO,2) = TURN
1480 E%(RDO,0) = MEMTYM
1490 RDO = RDO + 1
1500  RETURN
1510  HGR2 : POKE  - 16302,0: HPLOT
     130,95 TO 130,105: HPLOT 125
     ,100 TO 135,100
1511  IF AGAIN = 1 THEN 1517
1515  HPLOT 0,190 TO TURN,190: HPLOT
     FINISH,190
1516  RETURN
1517  HPLOT 0,190 TO L1,190: HPLOT
     RDO,190
1519  RETURN
1520  TEXT : HOME
1530  HTAB 15: VTAB 12
1540  PRINT "TOO SLOW"
1550  FOR J = 1 TO 500: NEXT J
1560  GOSUB 1510
1570 KT = 1
1580  RETURN
1590  TEXT : HOME
1600  HTAB 15: VTAB 12
1610  PRINT "WRONG RESPONSE"
1620  FOR J = 1 TO 500: NEXT J
1630  GOSUB 1510
1640 KT = 1
1650  RETURN
1660  TEXT : HOME
1670  HTAB 15: VTAB 12
1680  PRINT "ANTICIPATION"
1690  FOR J = 1 TO 500: NEXT J
1700  GOSUB 1510
1710 KT = 1
1720  RETURN
```

APPENDIX 3

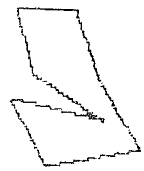


1

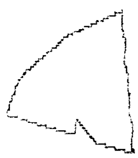


2

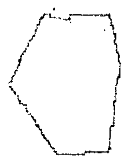
3



4



5



6

7

8

Upright representations of the stimuli used during the experiment.
(Numbering is that used throughout to describe stimuli).

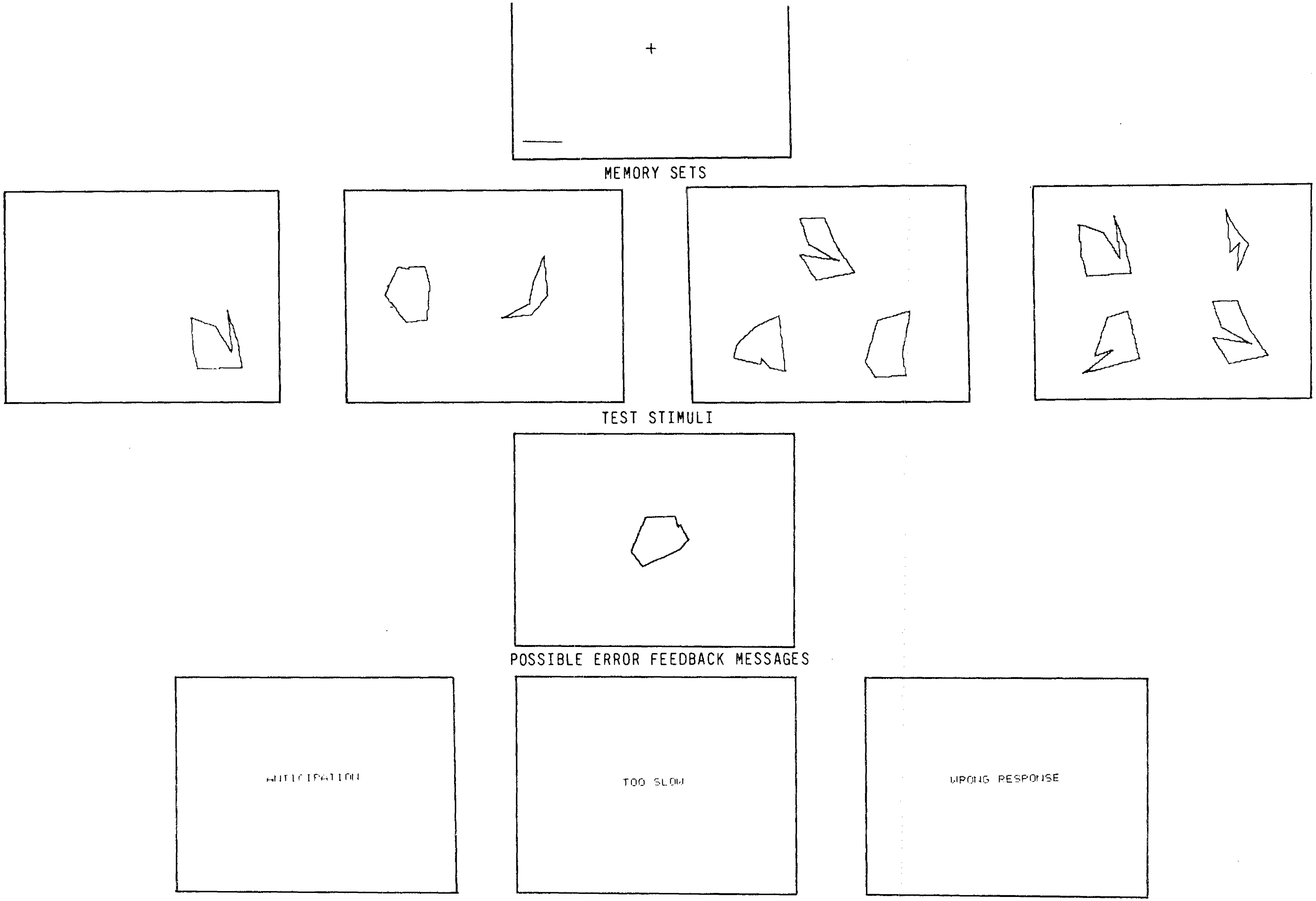


Diagram showing sequence of displays used during a trial

LOW IMAGERY GROUP

MATCH

	0			60			120			180		
	H	M	L	H	M	L	H	M	L	H	M	L
MEMORY LOAD = 1	799	989	939	1355	1594	1355	1312	1417	1553	1506	1416	1567
MEMORY LOAD = 2	1089	1154	1088	1405	1626	1476	1544	1601	1570	1620	1953	1745
MEMORY LOAD = 3	1217	1550	1218	1923	1777	1581	2138	1949	1767	2253	2060	2096
MEMORY LOAD = 4	1198	1610	1419	2255	2105	1877	1781	2226	2060	2274	2181	2580

NON-MATCH:MIRROR IMAGE

	0			60			120			180		
	H	M	L	H	M	L	H	M	L	H	M	L
MEMORY LOAD = 1	814	964	854	906	1084	853	913	995	919	943	840	929
MEMORY LOAD = 2	895	1109	963	928	884	924	1097	1357	1149	1020	986	1031
MEMORY LOAD = 3	1204	1677	996	1232	1279	1221	1278	1295	1261	1189	1318	1142
MEMORY LOAD = 4	1692	1481	1521	1362	1569	1468	1399	1725	1641	1469	1573	1813

NON-MATCH:DIRRERENT

	0			60			120			180		
	H	M	L	H	M	L	H	M	L	H	M	L
MEMORY LOAD = 1	1594	1608	1566	1309	1591	1466	1723	1721	1628	1511	1813	1689
MEMORY LOAD = 2	1650	1818	1542	1731	1421	1668	1603	1687	1965	1768	2452	1603
MEMORY LOAD = 3	1959	1877	1940	2158	1671	1959	1870	2000	1854	1724	1949	2221
MEMORY LOAD = 4	1798	2088	1995	1839	1791	2241	2179	2367	2541	1829	1995	2343

HIGH IMAGERY GROUP

MATCH

	0			60			120			180		
	H	M	L	H	M	L	H	M	L	H	M	L
MEMORY LOAD = 1	809	998	948	1526	1560	1115	1426	1918	1533	1541	1560	1523
MEMORY LOAD = 2	1102	1223	1071	1442	1603	1263	1311	1736	1415	1749	1641	1682
MEMORY LOAD = 3	1125	1150	1107	1755	1524	1164	1531	1678	1491	1773	1771	1593
MEMORY LOAD = 4	1154	1481	1229	1732	1844	1774	1593	2023	1644	2181	1708	2053

NON-MATCH:MIRROR IMAGE

	0			60			120			180		
	H	M	L	H	M	L	H	M	L	H	M	L
MEMORY LOAD = 1	789	887	842	914	1037	867	913	1074	918	873	812	865
MEMORY LOAD = 2	1015	1193	1228	1137	1110	1021	1217	1136	1197	1023	993	1278
MEMORY LOAD = 3	1161	1460	1031	914	978	927	1094	1117	1343	1443	1109	1409
MEMORY LOAD = 4	1333	1781	1399	1376	1570	1376	1357	1299	1651	1367	1295	1709

NON-MATCH:DIRRERENT

	0			60			120			180		
	H	M	L	H	M	L	H	M	L	H	M	L
MEMORY LOAD = 1	1643	1480	1432	1552	1868	1333	1575	1693	1707	1842	1980	1727
MEMORY LOAD = 2	1422	1416	1537	1577	1505	1340	1576	1790	1664	2170	1767	1957
MEMORY LOAD = 3	1302	1514	1412	1995	1900	1575	1744	1678	1545	1775	1867	1757
MEMORY LOAD = 4	1718	1847	1695	1915	1793	1741	1573	1947	1636	2208	1868	1939

KEY

H = Hypothesised high landmark feature saliency

M = Hypothesised medium landmark feature saliency

L = Hypothesised low landmark feature saliency

Results and mean values from the initial ANOVA with 'Saliency' as a factor

RESULTS FROM OVERALL ANOVA

Imagery Groups x Memory Load x Type of Match x Landmark Feature Saliency x Test Stimulus Orientation x Subjects.

Memory Load x Type of Match x Test Stimulus Orientation F (18,108) = 2.15, $p < .025$.

Type of Match x Landmark Feature Saliency x Test Stimulus Orientation F (12,72) = 2.03, $p < .025$.

Type of Match x Orientation F (6,36) = 17.9, $p < .001$.

Landmark Feature Saliency x Test Stimulus Orientation F (6,36) = 3.55, p .025.

Memory Load F (3,18) = 10.92, $p < .001$.

Type of Match (2,12) = 30.49, $p < .001$.

Landmark Feature Saliency F (2,12) = 5.62, $p < .025$.

Test Stimulus Orientation F (3,18) = 16.6, $p < .001$.

SINGLE SWITCH TASKS WITH CHILDREN:
ANALYSIS CONSIDERATIONS

APPENDIX

CONTENTS

APPENDIX 1

APPENDIX ONE

SOFTWARE ALGORITHMS

The software which controls the computerised cause and effect task as a subject interacts with it is is divided into two seperate programs. There is a foreground control task (written in high level FORTH) and a background interrupt-driven data gathering task (written in machine code). These two independent tasks both operate according to a simple multitasking system. The tasks synchronize their activities and communicate their states to each other by means of semaphore variables. These are variables written to by one of the programs as soon as it changes its own internal status in any way. The other program reads the semaphore at its own leisure, when it needs the information.

Data Gathering Task

All time critical processing is performed by a routine activated by a hardware generated interrupt, synchronised with the end of the screen update every 1/5Ø second. This interrupt stops the activity of the processor, and executes a low level machine language routine via an address vector. The interrupt routine has the responsibility for saving the status of the processor, executing its own code, restoring the processor status, and gracefully restarting the main program again. The speed and regularity of the interrupt routine means that it can be regarded as executing "simulateously" with the main routine.

APPENDIX 2

The first timing task, carried out at the start of each interupt is to increment a counter. This counter then acts as a software real-time clock, providing measurements accurate to within 2Ø milliseconds. Next, switch status is polled and if a change is detected the clock time is recorded. The time is also recorded whenever the control routine semaphores that it is starting a reward period, as is the particular value of the semaphore, which is then reset to zero. (This provides the data gathering routine with the capability to collect comparable data from more complex tasks, which can signal various changes in their state by storing different values in this semaphore location.) The interrupt routine stops collecting data once it has recorded 255 values.

APPENDIX 3

```
\*interrupt_routine*
SAVE_REGISTERS
Clock := Clock + 1
\ continue only if no data overflow will occur
IF Data_full_flag .NE. True
THEN
    \ gather reward data
    IF  Event_flag .NE. Ø
    THEN
        Event_type_array ( Event_index ) := Event_flag
        Event_time_array ( Event_index ) := Clock
        Event_flag := Ø
        \ reset so more can be detected
        Event_index := Event_index + 1
    ENDIF
    \ gather switch data
    IF  SWITCH .NE. Last_switch_state
    THEN
        Last_switch_state := SWITCH
        Switch_time_array ( Switch_index ) := Clock
        Switch_index := Switch_index + 1
        \ prevent data overflow
        IF   Switch_index .EQ. 256
        THEN
             data_full_flag := True
        ENDIF
    ENDIF
ENDIF
RESTORE_REGISTERS
EXIT
```

Pseudo-code representation of the algorithm for the data gathering interrrupt routine.

APPENDIX 4

Control Task

In contrast to the rapidly executing interrupt routine, the surface control program is written in a slower executing high level language and devotes most of its resources to controling reward presentation. When it needs to know about the occurrence of an event or the passing of time duration, it looks up the semaphore variables continually updated by the interrupt routine. It reacts when the contents of semaphores have passed a critical value or changed from their last known value.

The control routine begins with all rewards turned off and can move into one of two states: reward delivery and ending. The task ends if either the clock semaphore exceeds five minutes or a semaphore indicates that the data collecting routine has reached its limits for data storage. Reward activation occurs when a semaphore indicates switch activity. This semaphore is actually the offset index increased by the data gathering routine every time it stores the time of a switch state change. After rewards have been activated, run for their duration, and deactivated, the control routine re-reads and records the value of this index again. Any change from this new value will indicate more switch activity while the reward is inactive, triggering yet another reward. To allow recording of the precise timing of the start of reward activation, the control program sets a semaphore just before it begins the reward.

APPENDIX 5

```
\*surface_program*
\ initialization
Event_flag          := Ø
Event_index         := Ø
Switch_index        := Ø
Clock               := Ø
Switch_count        := Ø
Data_full_flag      := False
Last_switch_state := Off
START_INTERRUPT_PROGRAM
\ main loop
BEGIN
  IF Switch_index .GT. switch_count
  THEN
  \ a response has been signaled by the interrupt
program
    Event_flag := 255
    \ semaphore set to enable time to be recorded
    START_REWARD
    WAIT
    \ for the preset time period
    STOP_REWARD
    Switch_count := Switch_index
  ENDIF
IF Data_full_flag .EQ. False AND Clock .LT. 5_minutes
THEN
REPEAT
STOP_INTERRUPT_PROGRAMME
SAVE_DATA
END
```

Pseudo-code representation of the algorithm for the high level control task.

APPENDIX 6

Psuedo-code Listing Conventions

- All comments are in lowercase on a line preceeded by a backslash

e.g.

\ *a typical comment*

- Data storage structures have lower case names but begin with a capital letter.

e.g.

Clock

Event_flag

- Control structures are shown in uppercase and underlined.

e.g.

BEGIN REPEAT

IF THEN ENDIF

- Boolean truth tests follow FORTRAN conventions.

e.g.

.EQ. .NE. .GT. .LT.

- Executable procedural statements are in uppercase.

e.g.

START_INTERRUPT

WAIT

- Assignment is denoted with the target data structure to the right and the value to be assigned to the left.

e.g.

Clock := Ø

APPENDIX TWO

DATA TABLES FOR CASE STUDY ONE

This appendix contains numeric tables of the raw data for the first case study which involved a pictorial reward version of the cause and effect task. Each line beginning with an asterix ("*") denotes data for a seperate reward period. Immediately following each asterix is the time of the switch state change which initiated the reward period. All subsequent switch state change times within that reward period appear on the same line, or an indented following line. All values are times of a change of switch state as an offset from the start of the task. Times are stated in intervals of 1/50 of a second (jiffies). Following each time is either a "v" indicating that the switch was pressed or a "^" to indicate a switch release.

APPENDIX 8

Batch 1

```
*   3099v  3107^
*   3815v  3828^
*   4129v  4142^
*   4876v  4888^  5086v  5098^
*   5506v  5525^
*   6145v  6163^
*   6764v  6785^
*   7304v  7316^
*   8060v  8119^  8135v  8145^  8170v  8171^  8187v  8189^
    8203v  8206^  8217v  8221^
*   8398v  8417^
*   8735v  8748^
*   9459v  9479^  9620v
*   9791^
*  10537v 10568^ 10607v 10725^
*  10847v 10873^ 10979v
*  11617^ 11630v 11646^ 11669v 11688^ 11721v 11724^ 11735v
   11738^
*  11963v 11987^ 11996v 12005^ 12016v 12021^ 12031v 12035^
   12069v 12091^
*  12600v 12731^
*  13045v 13173^ 13225v 13230^
*  13453v
*  13789^ 13792v 13850^ 13864v 13898^ 13984v
*  14114^ 14360v 14387^
*  14423v 14534^
```

APPENDIX 9

Batch 2

```
*     0v
*   718^   783v   793^
*  1549v  1572^
*  2163v  2184^
*  4780v  4793^  4901v  4916^  4956v  4976^  5015v  5048^
*  5176v  5191^  5234v  5251^  5289v
*  5639^  5682v
*  6224^  6274v  6371^  6383v  6402^  6419v  6438^  6449v
   6455^
*  6557v  6594^  6617v  6660^  6676v  6826^
*  6890v  6907^  6938v  7146^
*  7219v  7238^  7248v
*  7531^  7789v
*  7807^  7876v  7924^
*  8129v  8146^
*  8534v  8554^
*  8981v  9010^  9034v  9168^
*  9435v  9682^
* 10116v 10131^ 10246v 10336^
* 10438v 10464^ 10521v 10659^
* 10913v 10939^ 11051v 11078^ 11098v 11123^ 11147v 11174^
* 11207v 11289^ 11307v 11327^ 11349v 11358^ 11383v 11401^
  11427v 11447^ 11474v
* 11493^ 11520v 11536^ 11560v 11570^ 11592v 11601^ 11620v
  11647^
* 12306v 12323^
* 13703v 13718^
* 14005v 14027^ 14039v 14088^
* 14826v 14840^ 14964v 14978^ 14995v 15039^ 15088v 15092^
```

APPENDIX 10

Batch 3

```
*   385v   396^
*  1008v  1021^
*  1284v
*  3279^
*  4169v  4185^
*  4726v  4775^
*  5578v  5599^
*  6835v  6839^  6942v  7004^
*  7517v  7574^  7664v  7776^
*  7913v  7929^
*  8258v  8266^  8316v  8322^  8323v  8324^  8327v  8328^
*  8848v  8855^
*  9306v  9329^
*  9931v  9937^
* 10299v 10304^ 10307v 10308^
* 10698v 10701^ 10706v 10710^ 10715v 10716^
* 11626v 11635^ 11640v 11641^
* 12488v 12497^ 12515v 12517^ 12527v 12531^
* 12915v 12943^
* 13907v 13912^
* 14321v 14324^ 14331v 14336^ 14346v 14583^ 14584v 14585^
* 14642v
* 14959^
```

APPENDIX 11

Batch 4

*	211v	213^	215v	233^				
*	949v	966^						
*	2605v	2608^	2614v	2622^	2682v	2715^		
*	4161v	4175^						
*	4673v	4689^	4697v	4699^	4701v	4713^	4714v	4715^
*	5200v	5202^	5210v	5211^				
*	5763v	5769^	5770v	5771^	5790v	5791^	5792v	5797^
	5843v	5918^						
*	6355v	6359^						
*	6668v	6810^	6830v	6836^	6862v	6896^		
*	7172v	7189^						
*	8005v	8023^						
*	9125v	9136^						
*	10306v	10309^	10310v	10313^	10318v	10319^	10321v	10323^
*	11270v	11271^	11275v	11276^	11277v	11283^	11284v	11290^
	11291v	11292^						
*	12749v	12757^	12763v	12771^	12779v	12790^	12791v	12801^
*	14039v	14042^	14058v	14067^				
*	14538v	14545^	14570v	14571^	14581v	14584^		

APPENDIX 12

Batch 5

```
*   500v   503^   529v   537^   566v   575^   638v   657^
*  1198v  1224^
*  1559v
*  1845^  1908v
*  2313^
*  3056v
*  3337^  3537v
*  4006^  4279v
*  4344^
*  5338v  5496^
*  6163v  6215^
*  6585v  6621^  6791v
*  6908^  6995v  7038^
*  7780v  7813^
*  9703v  9722^  9847v  9875^  9900v  9962^  9975v
* 10172^ 10185v
* 10578^ 10617v 10635^ 10723v 10790^
* 10999v 11238^
* 11423v 11494^
* 13110v
* 13450^ 13536v 13688^ 13706v
* 13725^
* 14297v 14322^ 14325v 14374^
* 14751v 14817^ 15003v
```

APPENDIX 13

Batch 6

```
*   364v   378^   510v
*   667^
*  1215v  1324^  1345v
*  1532^
*  2329v  2384^  2445v  2494^
*  2807v  2852^  2913v  2972^  2985v  3008^
*  3159v  3210^
*  3488v  3580^
*  4111v  4322^  4335v  4357^
*  4712v  4819^
*  5297v  5334^  5460v  5553^
*  5605v  5809^
*  5931v  5975^
*  6922v  7001^  7097v
*  7232^  7318v  7332^
*  7921v  7936^
*  8524v  8601^  8741v
*  9345^
*  9732v  9773^
* 10141v 10281^ 10368v 10369^
* 10497v 10501^ 10531v 10592^ 10698v 10719^ 10743v
* 10805^
* 11617v 11637^ 11851v
* 11976^
* 12627v 12635^
* 13033v
* 13661^
* 14109v
* 14916^ 14943v
```

APPENDIX 14

Batch 7

*	1804v	1852^						
*	2085v	2108^	2167v	2196^				
*	2441v	2532^	2621v	2697^				
*	2821v	2921^	2963v	3045^	3060v	3092^		
*	3173v	3269^	3295v	3372^	3385v	3409^	3421v	
*	3447^	3453v	3558^	3592v				
*	3731^	3802v	3844^	3935v				
*	4006^	4021v	4169^					
*	4357v	4463^						
*	4706v	4830^						
*	4984v	5058^						
*	5280v	5351^	5390v	5449^	5461v	5484^	5495v	5521^
	5533v							
*	5556^	5564v	5590^	5597v	5703^	5802v		
*	5877^	5902v	5996^	6117v				
*	6158^	6166v	6186^	6208v	6289^	6308v	6344^	6354v
	6379^	6391v	6416^	6422v				
*	6451^	6463v	6480^	6492v	6586^	6669v		
*	6869^	6878v	6906^	7072v				
*	7219^	7264v						
*	7594^	7603v	7626^	7633v	7697^			
*	7938v	7998^						
*	8484v							
*	8842^	8882v	8917^	9112v				
*	9142^	9168v	9212^	9237v	9263^	9274v	9296^	9300v
	9328^	9334v	9350^	9363v	9386^	9401v		
*	9426^	9443v	9476^	9590v	9653^	9668v		
*	9740^	9750v	9770^	9784v	9808^	9848v	10009^	
*	10031v	10065^	10105v	10156^	10169v	10198^	10208v	10285^
	10298v							
*	10320^	10333v	10359^	10378v	10409^	10425v		
*	10616^	10657v	10771^	10787v	10812^	10824v	10850^	10864v
*	10895^	10898v	10933^	10980v	11163^			
*	11177v	11292^						
*	11480v	11512^						
*	11860v	11876^						
*	12244v	12289^	12313v	12469^				
*	12544v	12629^						
*	12962v	13018^						

APPENDIX 15

Batch 8

```
*   408v   445^   549v
*  1217^
*  2941v
*  3216^
*  3762v  3766^
*  4323v  4369^
*  4827v  4851^
*  5192v  5290^  5337v  5341^  5352v  5411^
*  5585v  5611^
*  5934v  5959^  6111v  6155^  6179v
*  6252^  6293v  6303^
*  6589v  6598^  6608v  6614^  6621v  6623^  6624v  6625^
   6636v  6638^  6653v  6810^  6814v  6815^
*  6992v  6995^  6997v  6998^
*  7544v  7585^  7596v  7597^  7600v  7634^  7669v  7704^
   7734v
*  7864^  8074v  8075^
*  8427v  8483^  8501v  8526^  8527v  8529^  8530v  8532^
   8538v  8539^  8540v  8551^
*  9268v  9269^  9270v  9283^  9438v  9463^  9465v  9476^
*  9649v  9684^  9688v  9725^  9726v  9727^  9728v
*  9965^  9968v  9970^  9973v  9976^  9977v  9978^ 10006v
  10009^ 10010v 10012^ 10037v 10050^ 10058v 10060^ 10062v
  10068^
* 10478v 10483^ 10629v 10655^ 10700v
* 10891^ 10893v 10895^ 10897v 10898^ 10917v 10928^
* 11595v 11623^
* 11986v 12006^ 12007v 12010^ 12012v 12021^ 12023v 12024^
  12025v 12029^ 12030v 12031^ 12034v 12036^ 12037v 12110^
  12118v 12152^ 12174v
* 12290^ 12303v 12312^
* 12677v 12678^ 12679v 12716^ 12943v 12946^
* 12961v 13012^
* 13350v 13434^ 13510v 13514^
* 13637v 13664^ 13666v 13668^ 13670v 13680^
* 14147v 14178^ 14187v 14188^ 14190v 14197^ 14198v 14247^
  14249v 14250^ 14252v 14254^ 14255v 14293^ 14336v 14340^
* 14560v 14597^ 14609v 14717^
```

APPENDIX 16

Batch 9

```
*    10v    22^
*  1758v  1767^
*  2339v  2467^
*  4022v  4069^
*  4859v  4884^  4886v  4891^
*  8708v  8790^
*  9175v  9416^
* 10335v 10580^ 10608v
* 10625^ 10629v 10637^
* 12508v 12515^
```

APPENDIX 17

Batch 10

*	249v	348^	375v	501^				
*	1055v	1059^	1063v	1076^	1083v	1096^	1102v	1129^
	1151v	1191^	1289v	1291^	1292v	1293^		
*	1650v	1651^	1683v	1685^	1694v			
*	2111^							
*	2564v	2566^	2574v	2669^	2717v	2739^	2740v	2741^
*	2889v	3007^	3012v	3017^	3129v	3148^	3155v	
*	3173^	3175v	3336^	3339v	3341^	3342v	3354^	3360v
	3362^	3363v	3380^	3400v	3424^			
*	3461v	3502^	3651v	3668^	3670v	3672^	3683v	3693^
	3696v	3697^	3701v	3727^				
*	3749v	3770^	3801v	3815^	3817v	3851^	3852v	3853^
	3856v	3873^	3874v	3889^				
*	4141v	4184^						
*	4840v	4854^	4870v	4878^				
*	5416v	5467^	5477v	5514^	5552v	5568^	5593v	5614^
	5623v	5644^	5657v					
*	5977^	6006v	6017^	6026v	6051^	6124v	6127^	6129v
	6187^	6188v	6212^	6226v	6227^	6230v		
*	6258^	6265v	6289^	6297v	6304^	6306v	6307^	6325v
	6327^	6328v	6329^	6343v	6344^	6347v	6360^	6455v
	6483^							
*	6537v	6543^	6545v	6564^	6565v	6569^	6570v	6576^
	6577v	6810^						
*	6860v	6896^	6941v	7004^	7006v	7007^	7020v	7052^
	7064v	7117^						
*	7239v	7267^	7297v	7303^	7438v	7440^		
*	7583v	7618^	7657v	7659^	7707v			
*	7913^	7920v	7948^	8022v	8025^	8026v	8038^	8051v
	8062^	8065v	8066^	8067v	8068^	8079v	8111^	8112v
	8116^	8117v	8118^	8154v	8155^	8156v	8176^	
*	8242v	8260^	8333v	8345^	8358v	8360^	8361v	8369^
	8478v							
*	8520^	8565v	8621^	8646v	8653^	8657v	8669^	8670v
	8714^	8715v	8723^	8729v	8731^			
*	8811v	8816^	8839v	8843^	8933v	8980^	8994v	8995^
	8998v	9000^	9001v	9007^				
*	9383v	9388^	9389v	9435^	9533v	9546^		
*	9735v	9767^	9768v	9770^				
*	10075v	10130^	10140v	10141^	10175v	10176^	10177v	10182^
	10200v	10204^	10229v	10235^	10262v	10279^	10315v	
*	10366^	10415v	10424^	10427v	10453^	10454v		
*	10739^							
*	11328v	11330^	11333v	11338^	11342v	11361^	11362v	11364^
	11406v	11415^	11419v					

APPENDIX 18

Batch 11

```
*    83v   105^   121v   161^   314v
*   593^
*  1857v  2070^
*  2426v
*  2854^
*  3178v  3208^
*  3558v  3608^
*  5150v  5167^
*  6505v  6722^
*  8161v
*  8590^  8838v
*  8874^  9054v  9119^
*  9194v  9202^
* 10672v 10816^
* 11083v 11200^
* 12219v 12302^
* 12976v 13063^
* 13548v 13574^
* 13961v 13978^
* 14688v 14702^
```

APPENDIX 19

Batch 12

```
*   1569v  1581^
*   2341v  2347^
*   2962v  2968^  2971v  3003^
*   3952v  3996^
*   4696v  4726^
*   5162v  5167^  5181v  5207^  5208v  5209^
*   5933v  5943^  5950v  5962^
*   6426v  6453^
*   7308v  7311^  7328v  7329^  7331v  7339^
*   7747v  7791^
*   8171v  8234^
*   8601v  8628^  8634v  8638^
*   8946v  8979^  8981v  8985^  8995v  8996^  8997v  8998^
*   9381v  9415^
*   9730v  9761^
*  10140v 10145^ 10146v 10160^
*  10534v 10549^ 10550v 10589^
*  10902v 10912^ 10913v 10916^ 10917v 10923^ 10924v 10930^
   11134v 11141^ 11142v 11149^ 11150v 11156^ 11157v 11171^
   11172v
*  11178^ 11302v 11303^ 11305v 11306^ 11313v 11314^ 11316v
   11318^ 11327v 11330^
*  11546v 11547^ 11550v 11551^ 11552v 11565^ 11566v 11577^
   11578v 11586^
*  11893v 11969^
*  12218v 12271^
*  12543v 12590^ 12694v 12695^ 12710v 12716^ 12729v 12742^
*  12879v 12902^
*  13559v 13641^ 13643v 13644^ 13645v 13646^ 13647v 13651^
   13658v 13659^ 13660v 13666^ 13668v 13669^ 13691v 13692^
   13706v 13707^ 13709v 13710^ 13711v 13716^ 13718v 13731^
   13733v 13762^ 13763v 13765^ 13766v 13768^ 13769v 13771^
   13772v 13774^ 13775v 13778^ 13779v 13781^ 13782v 13786^
   13787v 13791^ 13792v 13796^ 13797v 13800^
*  13914v 13965^ 13966v 13968^ 13973v 13974^ 13984v 13985^
*  14298v 14299^ 14304v 14305^ 14318v 14319^ 14320v 14321^
   14323v 14324^ 14326v 14327^ 14329v 14330^ 14336v 14337^
   14340v 14341^ 14345v 14346^
*  14703v 14704^ 14705v 14708^ 14709v 14720^ 14721v 14744^
   14745v 14756^
```

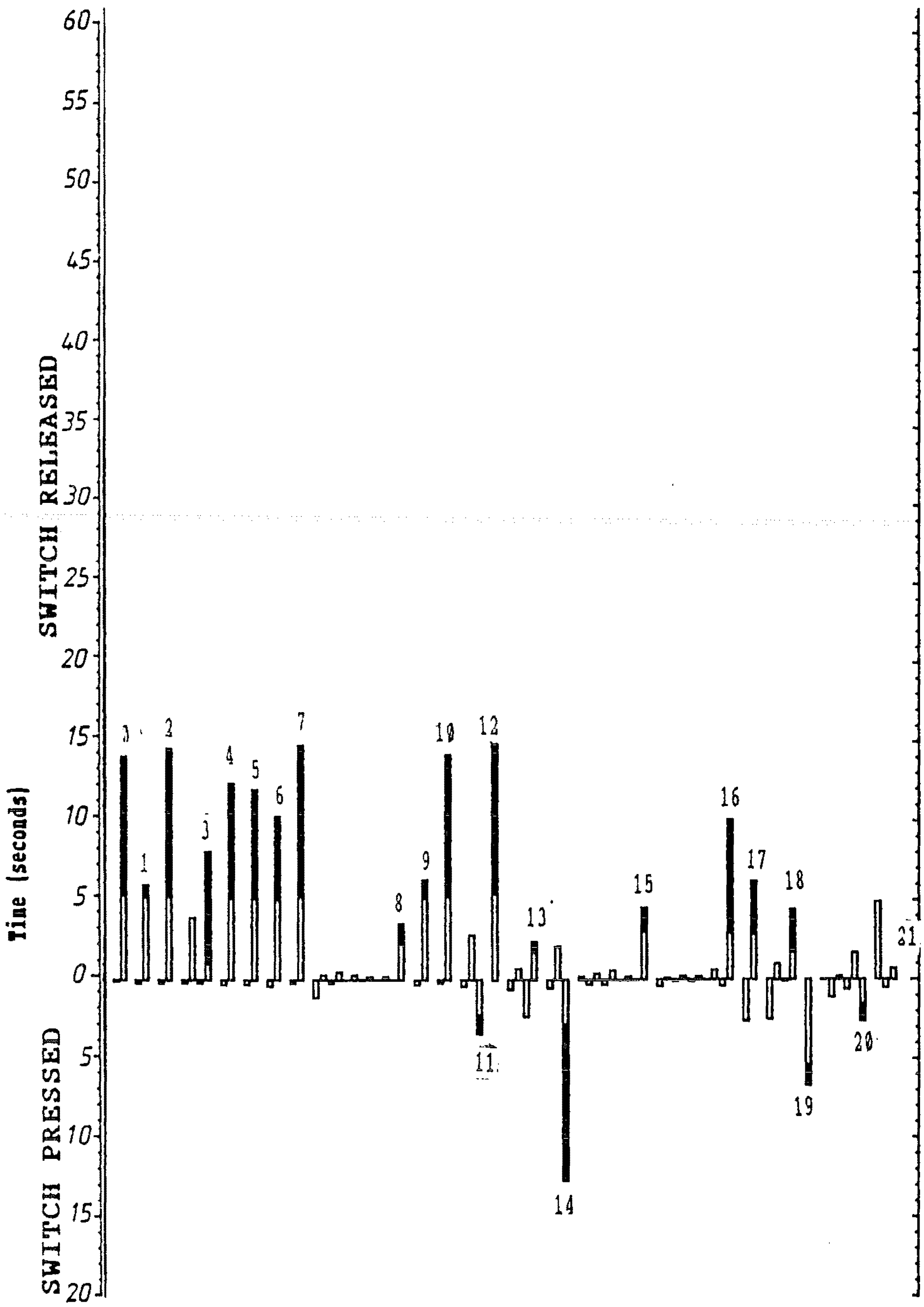
APPENDIX THREE

BAR GRAPHS FROM CASE STUDY ONE

This appendix contains bar graph displays as explained in Chapter VIII. In these displays the duration that the switch is in the alternating up and down states, is shown by the length of bars on the graph. Bars rising above the mid-line depict intervals in which the switch is up, and times for which the switch is held down, are shown in offset bars that fall below the mid-line. The vertical axis is marked in intervals of one second and times are plotted with a resolution of 2/50ths of a second. Reward periods are separated by gaps along the horizontal axis between runs of bars, and are numbered sequentially from the start of the task. These numbers are placed at the end of the last state duration bar of a period. The terminal black shaded area, within each last state duration bar for a reward period, denotes time during which the reward was inactive.

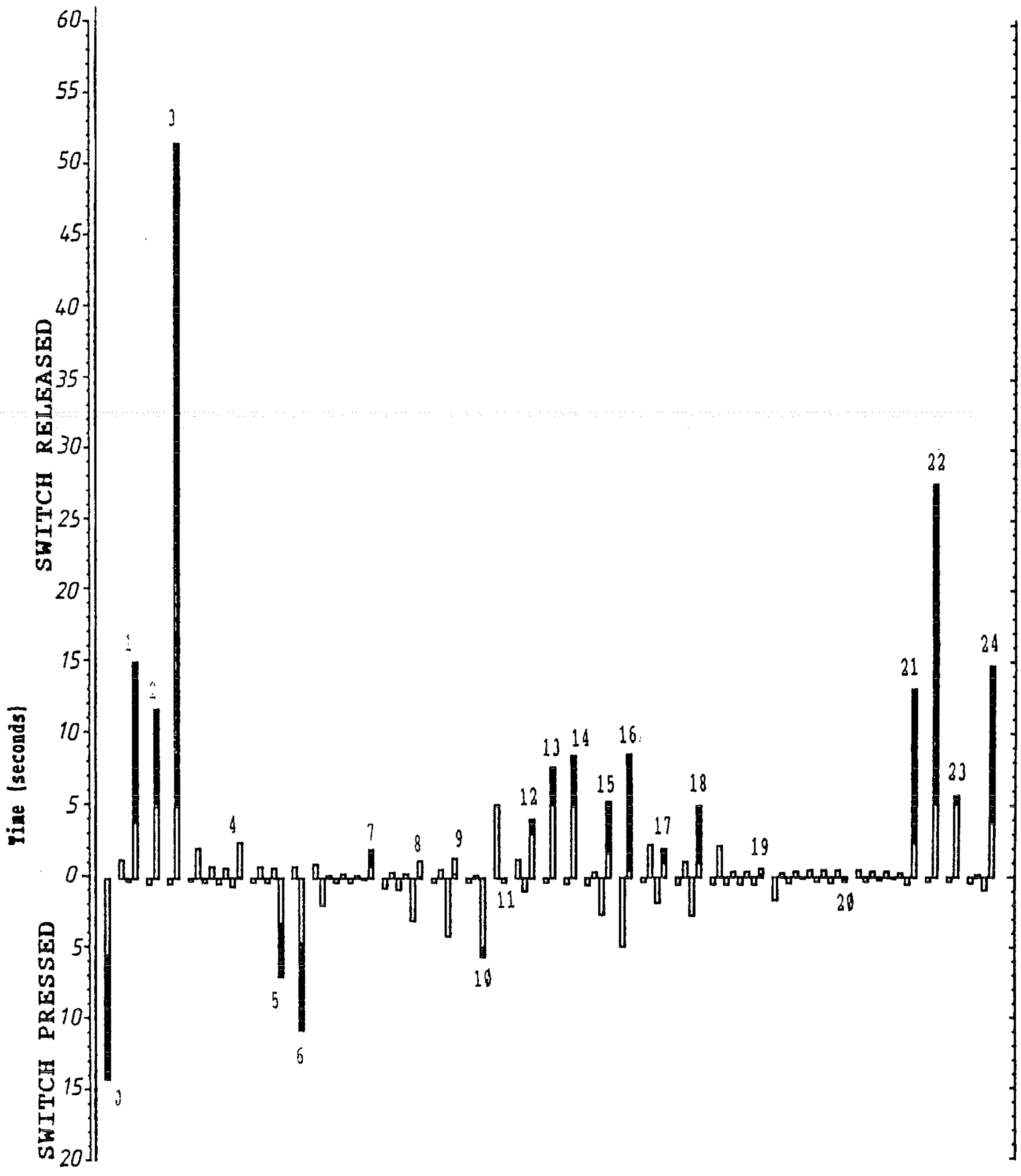
APPENDIX 21

Batch 1



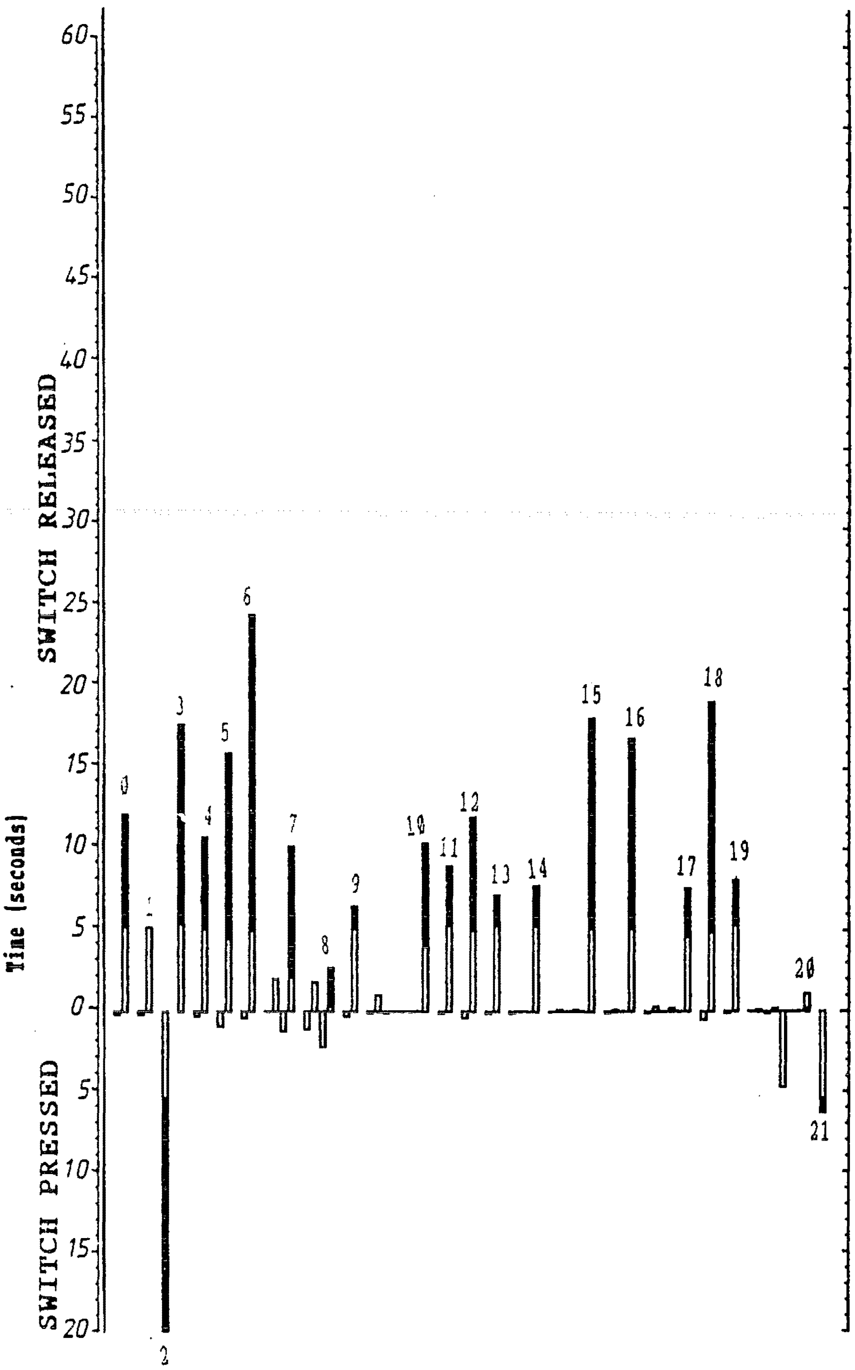
APPENDIX 22

Batch 2



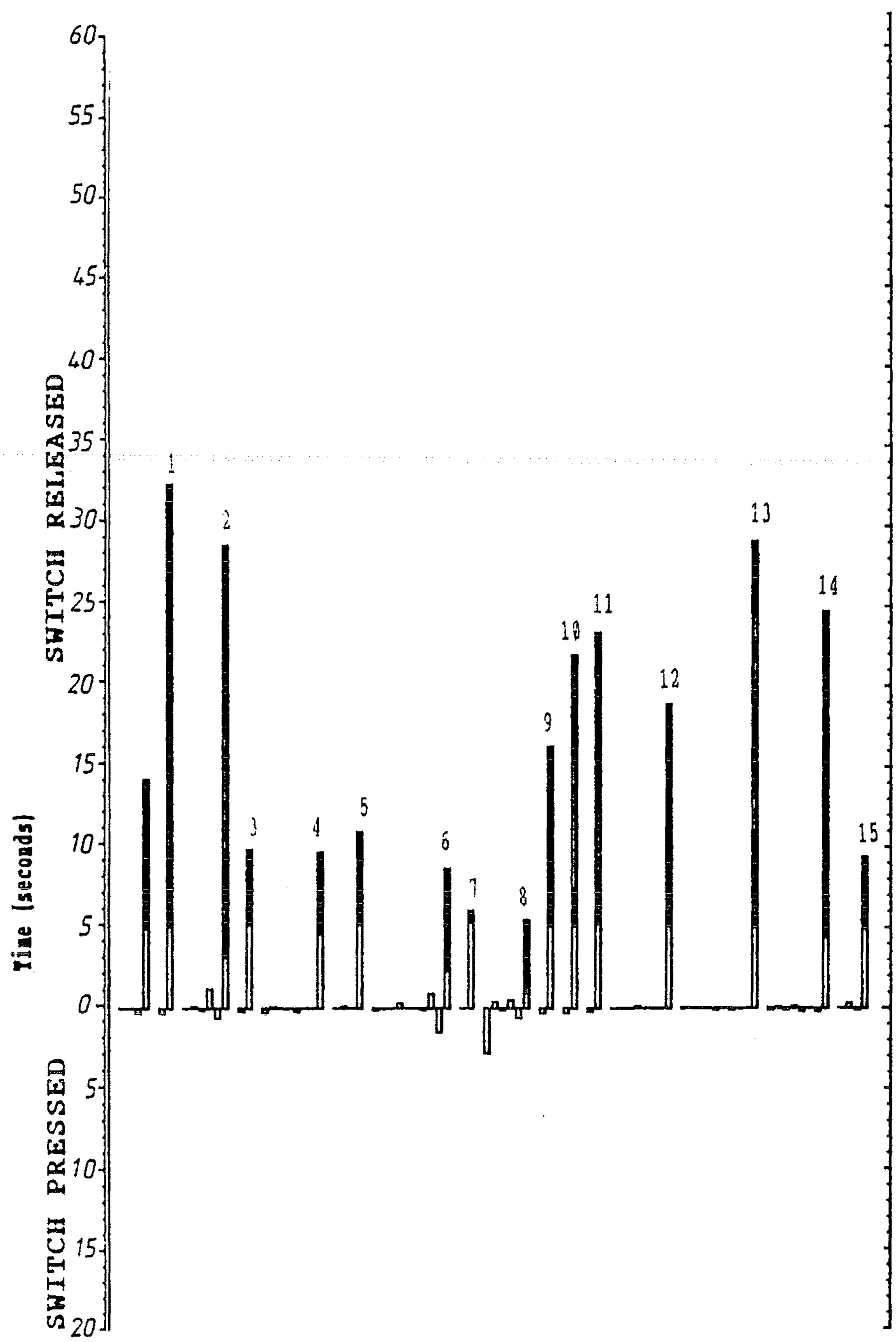
APPENDIX 23

Batch 3



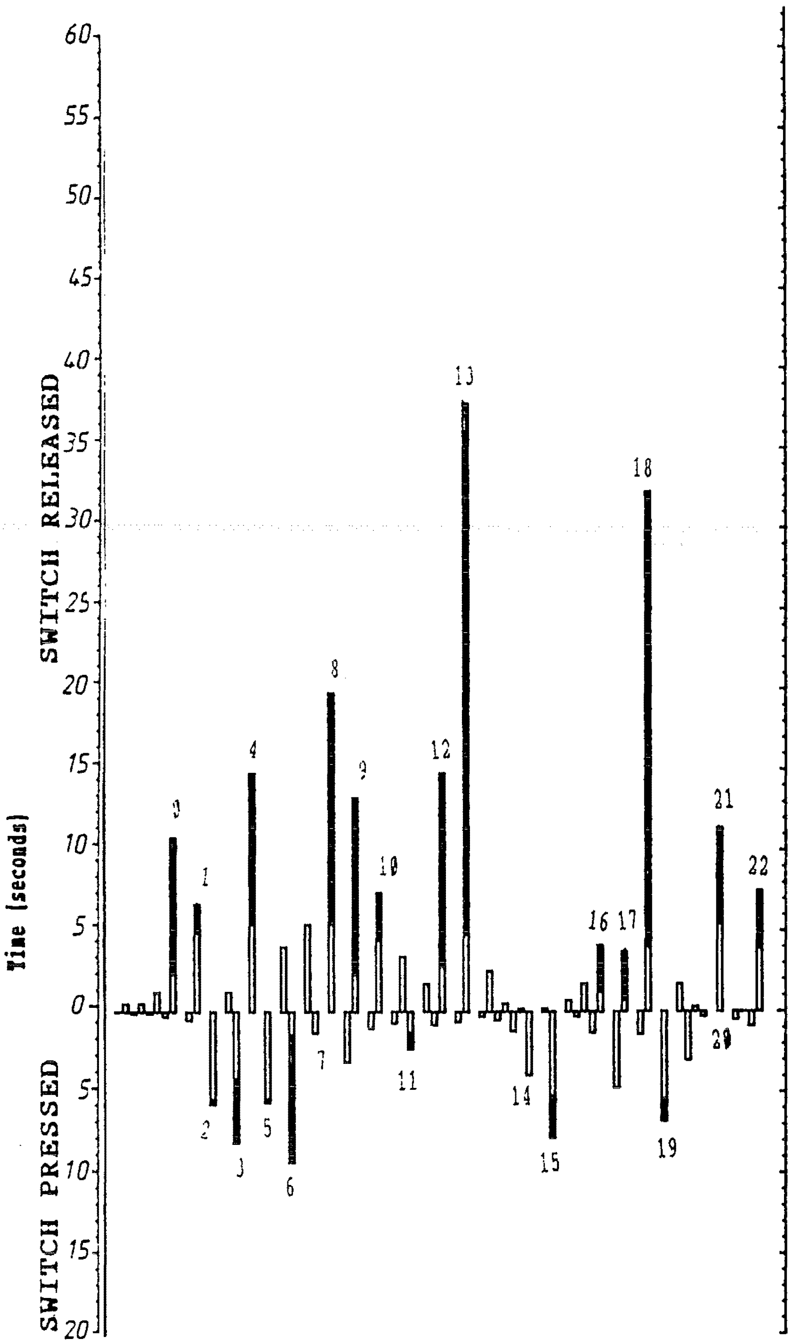
APPENDIX 24

Batch 4



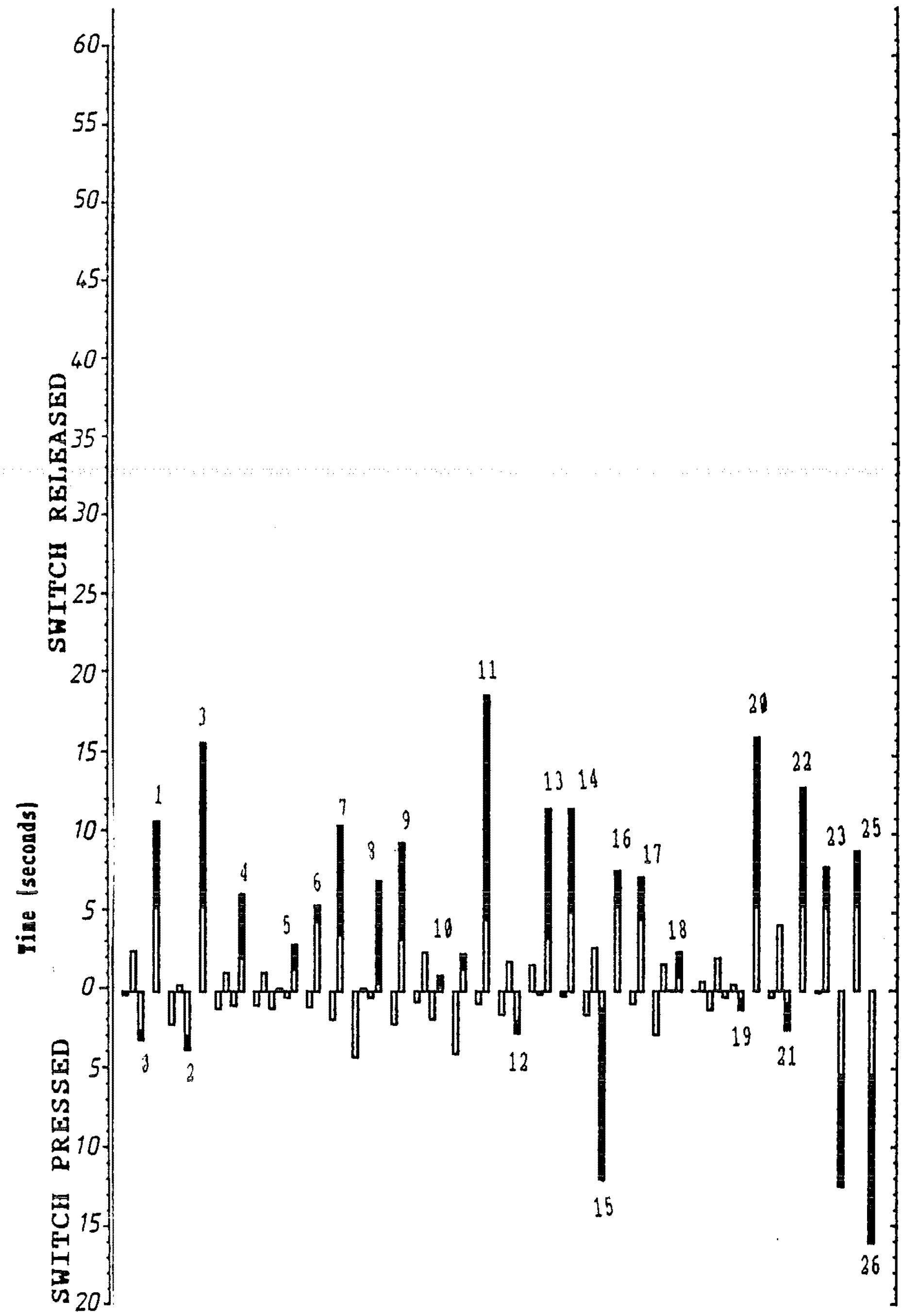
APPENDIX 25

Batch 5



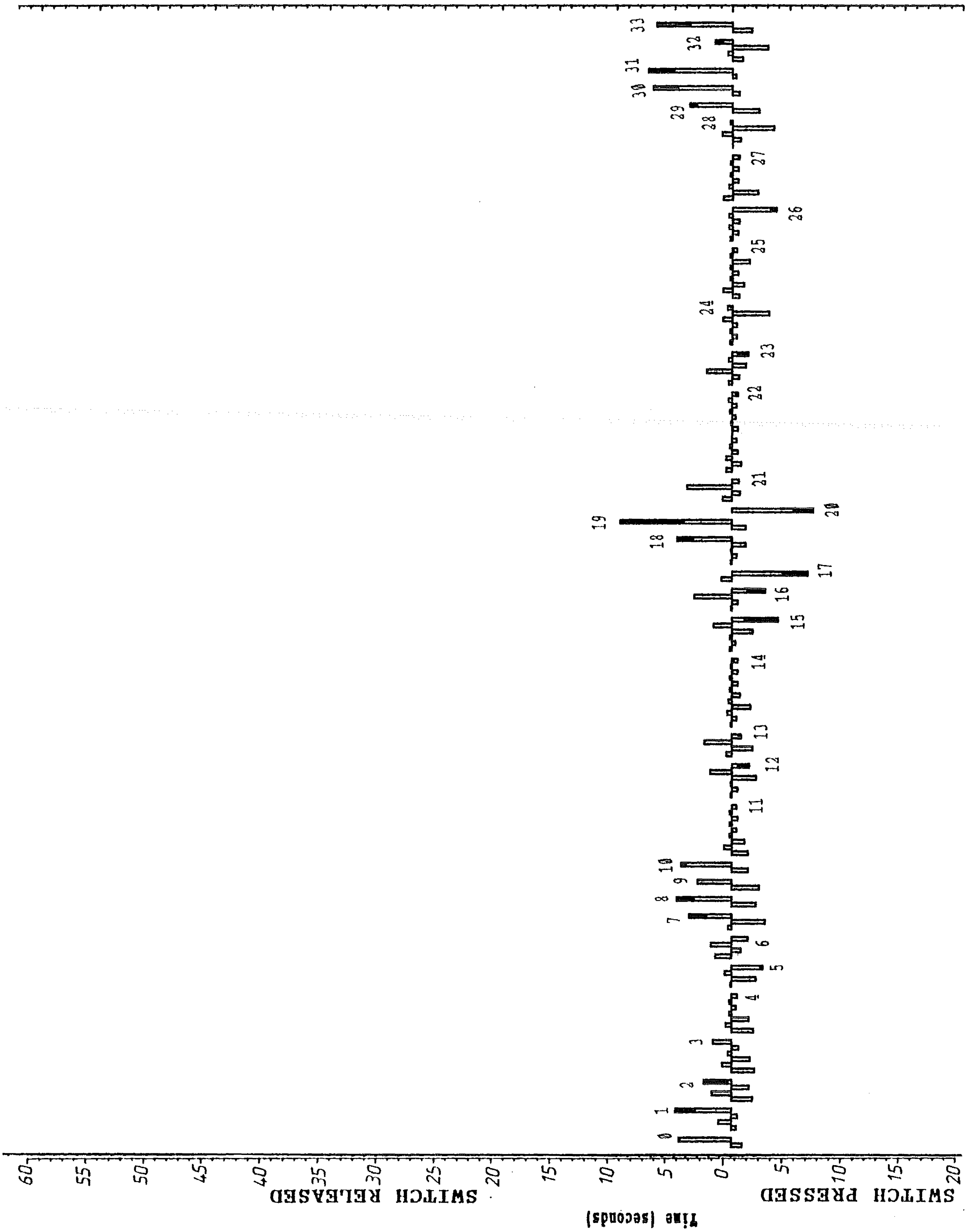
APPENDIX 26

Batch 6

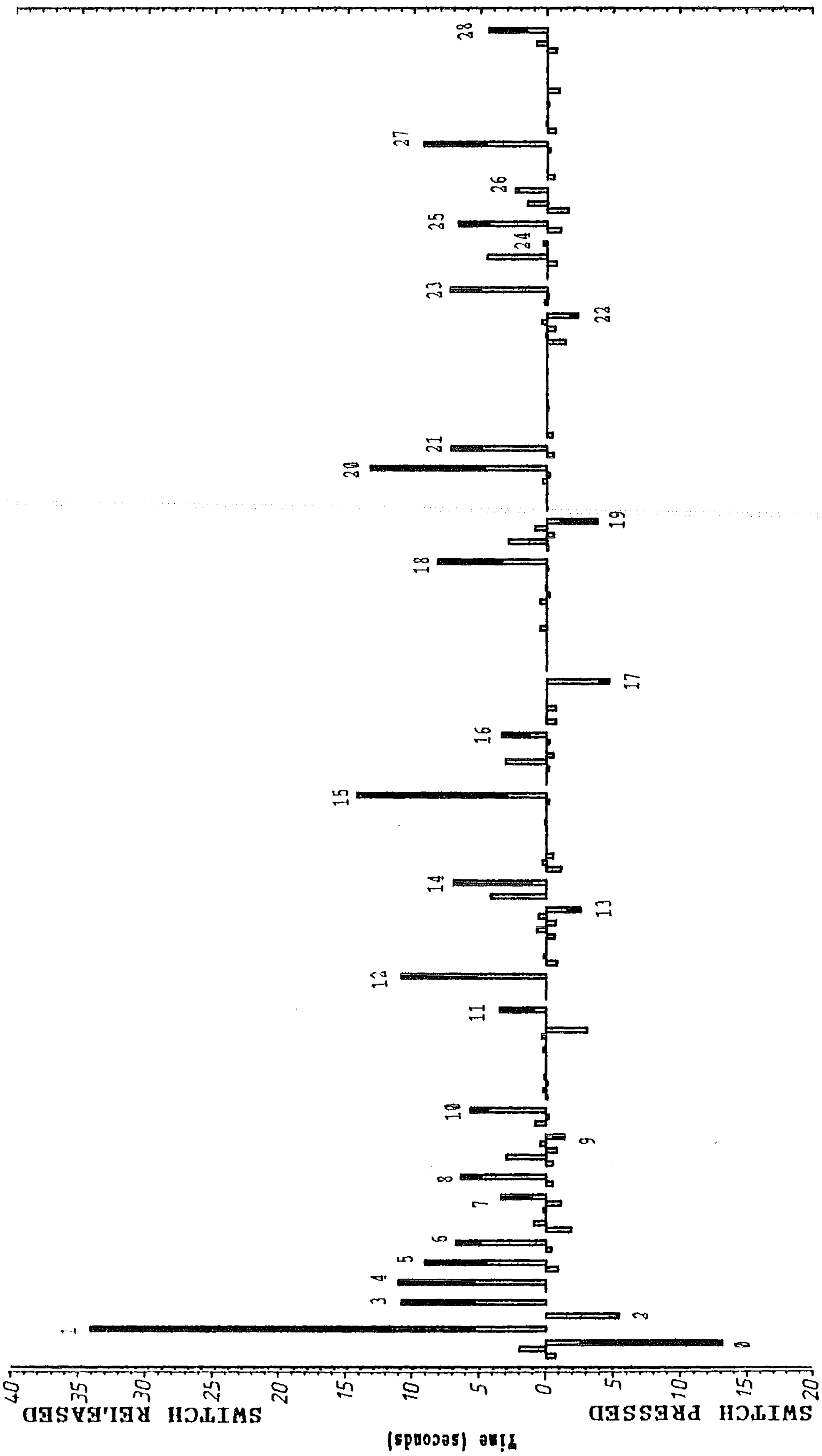


APPENDIX 27

Batch 7

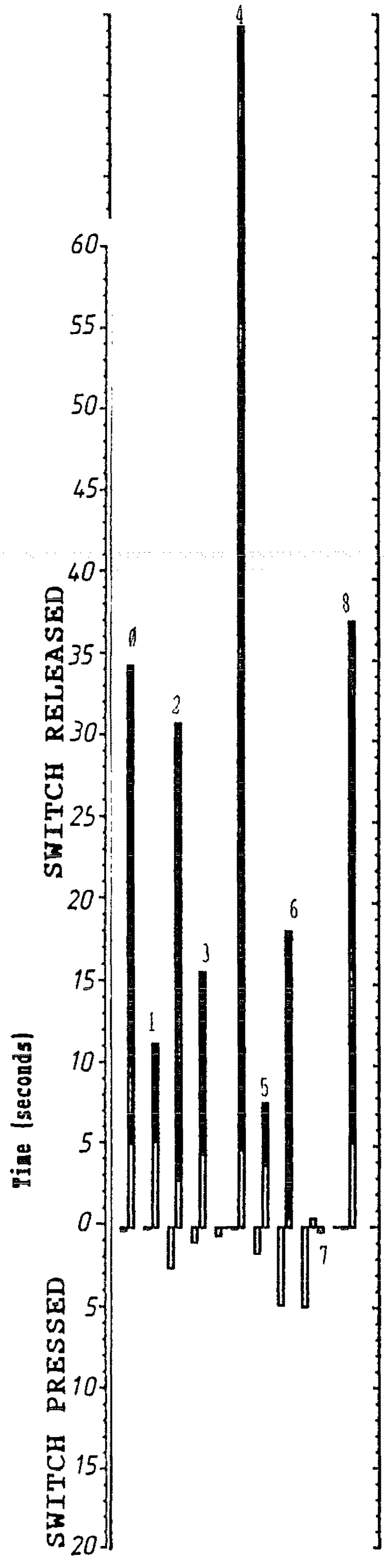


Batch 8


SWITCH RELEASED
SWITCH PRESSED
Time (seconds)
40 35 30 25 20 15 10 5 0 5 10 15 20
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28

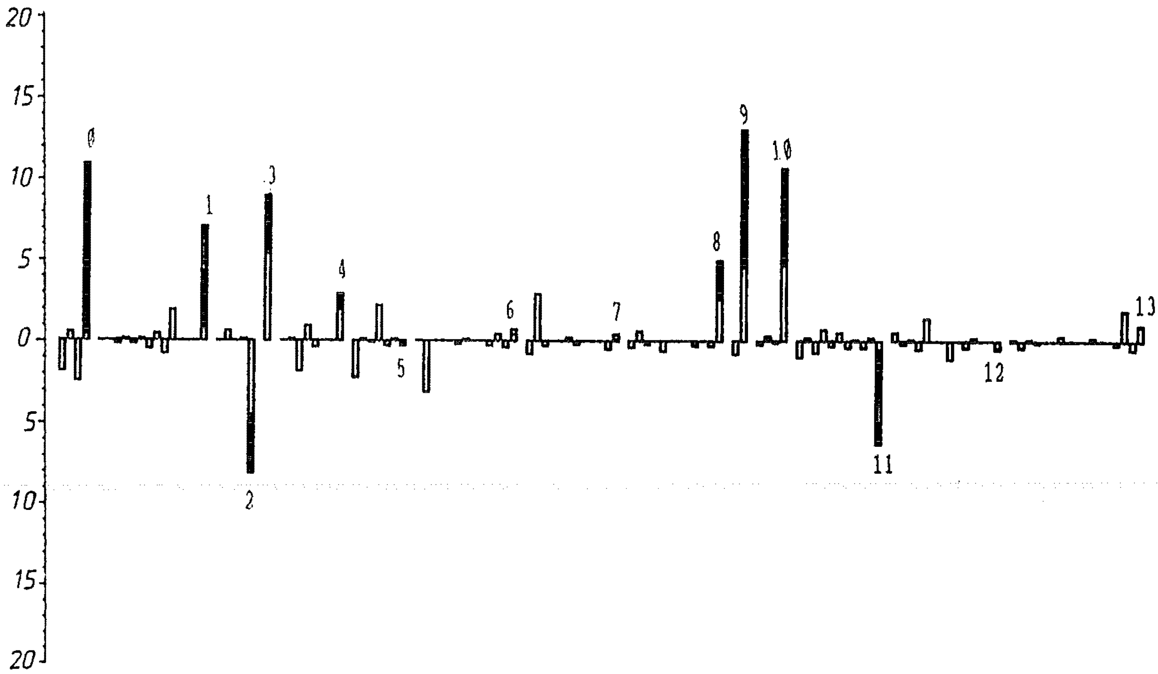
APPENDIX 29

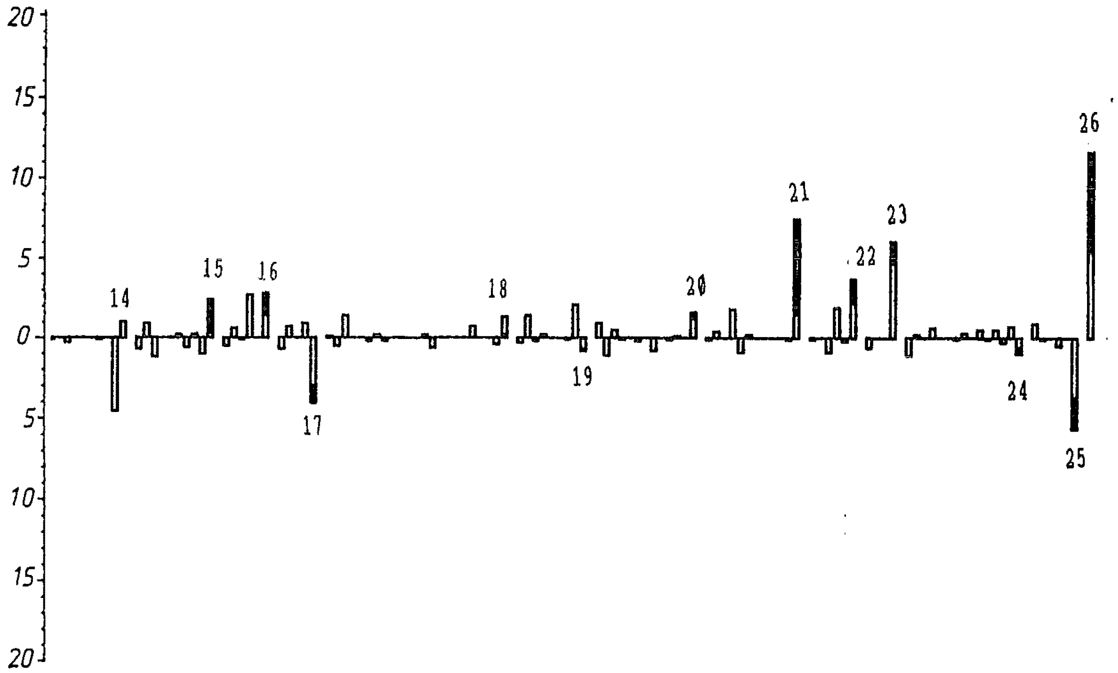
Batch 9



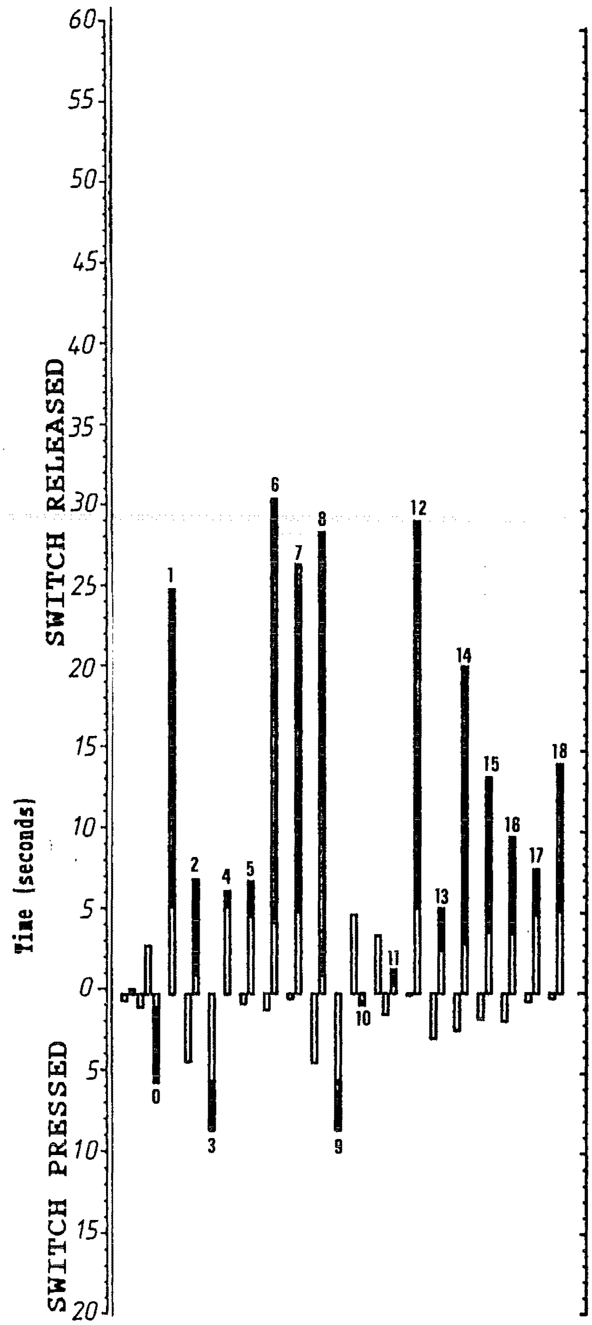
APPENDIX 3Ø

Batch 1Ø





Batch 11


SWITCH RELEASED
SWITCH PRESSED
Time (seconds)
60
55
50
45
40
35
30
25
20
15
10
5
0
5
10
15
20
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

APPENDIX 32

Batch 12

APPENDIX FOUR

FEATURE BY PERIOD TABLES FROM CASE STUDY ONE

APPENDIX 34

Batch 1

```
:0123456789012345678901:-----------------------------------
:*********** ** ****  *:UP
:           *  *    ** :DN
:           *  *       :ALT?
:          * ** *      :ADD
:          ******      :ALT1
:                      :ALT
:                      :UNAMBIGUOUS
:                      :OPTIMAL.ALT
:                      :SIMPLE.ALT
:                      :FAST.ALT
:                      :SLOW.ALT
:                      :*ALT
:0123456789012345678901:-----------------------------------
:*********** *  ****  *:RELEASE         Often      Runs
:*********** *  ****   :ENDS_UP         Often      Clusters
:*** ******* *  ***    :SIMPLE.P/R      Often      Runs
:*** **** ** *    *    :PAUSED          Sometimes  Runs
:*** **** ** *    *    :OPTIMAL.P/R     Sometimes  Runs
:******** ** *    **  *:FEW.P/R         Often      Runs
: *      **     * **  *:FAST.P/R        Sometimes  Runs
:* ******  * *   *     :SLOW.P/R        Sometimes  Runs
:*********** *  ****   :*P/R
:0123456789012345678901:-----------------------------------
:           *  *    *  :HOLD            Infrequent Runs
:           *  *    *  :ENDS_DN         Always     Runs
:                   *  :SIMPLE.HOLD     Sometimes  Isolated
:                   *  :PAUSED.DN       Sometimes  Isolated
:                   *  :OPTIMAL.HOLD    Sometimes  Isolated
:           *  *    *  :FEW.HOLD        Always     Runs
:           *       *  :FAST.HOLD       Sometimes  Runs
:              *       :SLOW.HOLD       Sometimes  Isolated
:           *  *    *  :*HOLD
:0123456789012345678901:-----------------------------------
:        *      **   * :RUN             Infrequent Runs
:                      :NO_TAIL         Never      None
:        *      **     :QUICK_DN        Sometimes  Runs
:                    * :QUICK_UP        Sometimes  Isolated
:        *      **   * :*RUN
:0123456789012345678901:-----------------------------------
:                      :ALT  Never      None       Absent
:*********** *  ****  *:P/R  Often      Runs       Major
:           *  *    *  :HLD  Infrequent Runs       Minor
:        *      **   * :RUN  Infrequent Runs       Minor    (poor)
:             *        :UNCLAIMED
```

APPENDIX 35

Batch 2

```
:0123456789012345678901234:-----------------------------------
: ****  *   ****** *  ****:UP
:*    ** ***     *        :DN
:       *                 :ALT?
:      * *                :ADD
:      ***                :ALT1
:                         :ALT
:                         :UNAMBIGUOUS
:                         :OPTIMAL.ALT
:                         :SIMPLE.ALT
:                         :FAST.ALT
:                         :SLOW.ALT
:                         :*ALT
:0123456789012345678901234:-----------------------------------
: ***       ****** *  ****:RELEASE         Sometimes  Clusters
: ***        ***** *  ****:ENDS_UP         Often      Clusters
: ***        *** *    ****:SIMPLE.P/R      Often      Clusters
:  **         ** *     ** :PAUSED          Sometimes  Runs
:  **       * ** *     ** :OPTIMAL.P/R     Sometimes  Runs
: ***       ****** *   ***:FEW.P/R         Often      Clusters
:           *****  *    * :FAST.P/R        Sometimes  Clusters
: ***            *    ** *:SLOW.P/R        Sometimes  Clusters
: ***        *** *     ***:*P/R
:0123456789012345678901234:-----------------------------------
:*    ** ***     *        :HOLD            Infrequent Clusters
:*    **   *              :ENDS_DN         Sometimes  Runs
:*    **   *     *        :SIMPLE.HOLD     Sometimes  Runs
:*     *   *     *        :PAUSED.DN       Sometimes  Runs
:*     *         *        :OPTIMAL.HOLD    Sometimes  Runs
:*     *  **     *        :FEW.HOLD        Sometimes  Runs
:     *  ***              :FAST.HOLD       Sometimes  Clusters
:*     *         *        :SLOW.HOLD       Sometimes  Runs
:*    ** ***     *        :*HOLD
:0123456789012345678901234:-----------------------------------
:    *  **          ***   :RUN             Infrequent Clusters
:        *          **    :NO_TAIL         Sometimes  Runs
:    *  *           ***   :QUICK_DN        Often      Runs
:        *           *    :QUICK_UP        Sometimes  Runs
:    *  **          ***   :*RUN
:0123456789012345678901234:-----------------------------------
:                         :ALT  Never      None       Absent
: ***       ****** *  ****:P/R  Sometimes  Clusters   Notable
:*    **  **              :HLD  Infrequent Clusters   Minor
:    *  **          ***   :RUN  Infrequent Clusters   Minor
:                 *       :UNCLAIMED
```

Batch 3

```
:0123456789012345678901:-----------------------------------
:** *****************  :UP
:  *                 **:DN
:  *                   :ALT?
: * *                  :ADD
: ***                  :ALT1
:                      :ALT
:                      :UNAMBIGUOUS
:                      :OPTIMAL.ALT
:                      :SIMPLE.ALT
:                      :FAST.ALT
:                      :SLOW.ALT
:                      :*ALT
:0123456789012345678901:-----------------------------------
:** ***** ***********  :RELEASE         Often      Runs
:** ***** ***********  :ENDS_UP         Always     Runs
:** ****  ***********  :SIMPLE.P/R      Often      Clusters
:** ****  * *********  :PAUSED          Often      Runs
:** ****  * ***    **  :OPTIMAL.P/R     Often      Runs
:** ***** * **** * **  :FEW.P/R         Often      Runs
: *       * * **  * *  :FAST.P/R        Sometimes  Runs
:*  *****  * *  ** *   :SLOW.P/R        Sometimes  Runs
:** ***** ***********  :*P/R
:0123456789012345678901:-----------------------------------
:  *                 **:HOLD            Infrequent Clusters
:  *                  *:ENDS_DN         Sometimes  Runs
:  *                  *:SIMPLE.HOLD     Sometimes  Runs
:  *                  *:PAUSED.DN       Sometimes  Runs
:  *                  *:OPTIMAL.HOLD    Sometimes  Runs
:  *                  *:FEW.HOLD        Sometimes  Runs
:                    **:FAST.HOLD       Sometimes  Clusters
:  *                   :SLOW.HOLD       Sometimes  Isolated
:  *                 **:*HOLD
:0123456789012345678901:-----------------------------------
:          *    * *  * :RUN             Infrequent Runs
:                    * :NO_TAIL         Sometimes  Isolated
:          *    * *    :QUICK_DN        Sometimes  Runs
:                    * :QUICK_UP        Sometimes  Isolated
:          *    * *  * :*RUN
:0123456789012345678901:-----------------------------------
:                      :ALT  Never      None       Absent
:** ***** ***********  :P/R  Often      Runs       Major   (good)
:  *                  *:HLD  Infrequent Runs       Minor   (good)
:          *         * :RUN  Infrequent Runs       Minor
:        *             :UNCLAIMED
```

Batch 4

```
:Ø123456789Ø12345:------------------------------------
:****************:UP
:                :DN
:                :ALT?
:                :ADD
:                :ALT1
:                :ALT
:                :UNAMBIGUOUS
:                :OPTIMAL.ALT
:                :SIMPLE.ALT
:                :FAST.ALT
:                :SLOW.ALT
:                :*ALT
:Ø123456789Ø12345:------------------------------------
:****************:RELEASE         Always     Block
:****************:ENDS_UP         Always     Block
:******** *******:SIMPLE.P/R      Often      Block
:** *** * *******:PAUSED          Often      Runs
: * *   * ***    :OPTIMAL.P/R     Sometimes  Runs
:** * * * ***   *:FEW.P/R         Sometimes  Runs
:   *   **      *:FAST.P/R        Infrequent Runs
:*** ***  ****** :SLOW.P/R        Often      Runs
:****************:*P/R
:Ø123456789Ø12345:------------------------------------
:                :HOLD
:                :ENDS_DN
:                :SIMPLE.HOLD
:                :PAUSED.DN
:                :OPTIMAL.HOLD
:                :FEW.HOLD
:                :FAST.HOLD
:                :SLOW.HOLD
:                :*HOLD
:Ø123456789Ø12345:------------------------------------
:  * * * *   *** :RUN             Sometimes  Runs
:                :NO_TAIL         Never      None
:  * * *     *** :QUICK_DN        Often      Runs
:                :QUICK_UP        Never      None
:  * * *     *** :*RUN
:Ø123456789Ø12345:------------------------------------
:                :ALT  Never      None       Absent
:****************:P/R  Always     Block      Major   (good)
:                :HLD  Never      None       Absent
:  *   * *       :RUN  Infrequent Runs       Notable (poor)
:                :UNCLAIMED
```

```
Batch 5
:01234567890123456789012:----------------------------------
:**  * ********  ***  **:UP
:  ** **  *    ** * **  :DN
:    **   *      ***    :ALT?
:   **** * *    *****   :ADD
:   **** ***    *****   :ALT1
:   ****        *****   :ALT              Sometimes   Clusters
:   ***         ** **   :UNAMBIGUOUS      Often       Clusters
:   ****        * ***   :OPTIMAL.ALT      Often       Clusters
:   ****        ** **   :SIMPLE.ALT       Often       Clusters
:   * *         *** *   :FAST.ALT         Sometimes   Runs
:    * *           *    :SLOW.ALT         Sometimes   Runs
:   ***         *  **   :*ALT
:01234567890123456789012:----------------------------------
:**  * ********  ***  **:RELEASE          Often       Runs
:**  *   *** **  ***  **:ENDS_UP          Often       Runs
:**  * * *** **  * *  **:SIMPLE.P/R       Often       Runs
: *  * * ***  *    *  * :PAUSED           Sometimes   Runs
: *  * *****  *   **  * :OPTIMAL.P/R      Often       Runs
: *  * ********   **  **:FEW.P/R          Often       Runs
: *     *  **    **    *:FAST.P/R         Sometimes   Runs
:*   * * **  **    *  * :SLOW.P/R         Sometimes   Runs
: *  *   ***  *    *  * :*P/R
:01234567890123456789012:----------------------------------
:  ** **  *    ** * **  :HOLD             Sometimes   Runs
:  ** **       **    *  :ENDS_DN          Sometimes   Runs
:  ** **  *     *   *   :SIMPLE.HOLD      Sometimes   Runs
:  ** **  *     *   *   :PAUSED.DN        Sometimes   Runs
:  ** **  *     * * *   :OPTIMAL.HOLD     Often       Runs
:  ** **  *     * * **  :FEW.HOLD         Often       Runs
:  ** *        ** * **  :FAST.HOLD        Often       Runs
:      *  *             :SLOW.HOLD        Sometimes   Runs
:  ** **  *     * * *   :*HOLD
:01234567890123456789012:----------------------------------
:*             *        :RUN              Infrequent Runs
:                       :NO_TAIL          Never      None
:*                      :QUICK_DN         Sometimes  Isolated
:                       :QUICK_UP         Never      None
:*             *        :*RUN
:01234567890123456789012:----------------------------------
:   ***         ** **   :ALT  Infrequent Clusters   Minor    (good)
:**  *  *******  ***  **:P/R  Often      Runs       Major
:  ** **       ** * **  :HLD  Sometimes  Runs       Notable
:*             *        :RUN  Infrequent Runs       Minor    (poor)
:                       :UNCLAIMED
```

Batch 6

```
:0123456789012345678901234567:-----------------------------------
: * *******  * ** **  **** * :UP
:* *     *  * *  *        * *:DN
: **     *   **  *        ** :ALT?
:****   * * ***** *      ****:ADD
:****   *** *******      ****:ALT1
:****       ****         ****:ALT              Sometimes   Clusters
:****       ****         ****:UNAMBIGUOUS      Always      Clusters
: * *       **           ****:OPTIMAL.ALT      Sometimes   Clusters
: * *        ***         ****:SIMPLE.ALT       Often       Clusters
:* *        * *          * * :FAST.ALT         Sometimes   Runs
: * *        * *          * *:SLOW.ALT         Sometimes   Runs
:****       ****         ****:*ALT
:0123456789012345678901234567:-----------------------------------
: * *******  * ** **  **** * :RELEASE          Often       Runs
: * *******  * ** **  * ** * :ENDS_UP          Often       Runs
: * ***** *  * ** **  * ** * :SIMPLE.P/R       Often       Mixed
: * *  ** *  *  * **  * ** * :PAUSED           Often       Mixed
: * *  ** *  *  * **  * ** * :OPTIMAL.P/R      Often       Mixed
: * ** ****  * ** **  **** * :FEW.P/R          Often       Runs
:    ***          **   * * * :FAST.P/R         Sometimes   Runs
: * *   ***  * **     * *    :SLOW.P/R         Sometimes   Runs
: * ** ****  * ** **  * ** * :*P/R
:0123456789012345678901234567:-----------------------------------
:* *     *  *    *        * *:HOLD             Infrequent  Runs
:* *             *        * *:ENDS_DN          Sometimes   Runs
:                         * *:SIMPLE.HOLD      Sometimes   Runs
:                         * *:PAUSED.DN        Sometimes   Runs
:           *             * *:OPTIMAL.HOLD     Sometimes   Runs
:* *     *  *    *        * *:FEW.HOLD         Always      Runs
:* *        *                :FAST.HOLD        Sometimes   Runs
:        *       *        * *:SLOW.HOLD        Sometimes   Runs
:* *     *  *    *        * *:*HOLD
:0123456789012345678901234567:-----------------------------------
:     *              *       :RUN              Infrequent  Runs
:                    *       :NO_TAIL          Sometimes   Isolated
:     *              *       :QUICK_DN         Always      Runs
:                            :QUICK_UP         Never       None
:     *              *       :*RUN
:0123456789012345678901234567:-----------------------------------
:            ***         ****:ALT  Infrequent Clusters    Minor    (good)
: * *******  * ** **  **** * :P/R  Often      Runs        Major    (good)
:* *     *  *    *        * *:HLD  Infrequent Runs        Minor
:     *              *       :RUN  Infrequent Runs        Minor
:          *        *        :UNCLAIMED
```

Batch 7

```
:0123456789012345678901234567890123:-----------------------------------
:***    ****     * ** *       *** *:UP
:     *         * *  *   * * *   * :DN
:                **  *           * :ALT?
:               ***** *         * *:ADD
:               *******         ***:ALT1
:               ****               :ALT             Infrequent Clusters
:               ****               :UNAMBIGUOUS     Always     Clusters
:                 *                :OPTIMAL.ALT     Sometimes  Isolated
:               * **               :SIMPLE.ALT      Sometimes  Runs
:               ****               :FAST.ALT        Always     Clusters
:                                  :SLOW.ALT        Never      None
:               ****               :*ALT
:0123456789012345678901234567890123:-----------------------------------
:**     ****     * ** *       *** *:RELEASE         Sometimes  Clusters
:**     ****       **         *** *:ENDS_UP         Often      Clusters
:**      ***       **         *** *:SIMPLE.P/R      Often      Clusters
:*       ***        *         *** *:PAUSED          Sometimes  Clusters
:*       ***        *         *** *:OPTIMAL.P/R     Sometimes  Clusters
:**     ****     *  * *       *** *:FEW.P/R         Often      Clusters
:**     ****     * *  *       *** *:FAST.P/R        Often      Clusters
:                   *              :SLOW.P/R        Infrequent Isolated
:**      ***        *         *** *:*P/R
:0123456789012345678901234567890123:-----------------------------------
:               * *  *   * * *   * :HOLD            Infrequent Mixed
:               * *  *     *       :ENDS_DN         Sometimes  Runs
:               * *  *     *       :SIMPLE.HOLD     Sometimes  Runs
:                 *  *             :PAUSED.DN       Sometimes  Runs
:                 *  *             :OPTIMAL.HOLD    Sometimes  Runs
:                 *  *           * :FEW.HOLD        Sometimes  Runs
:               * *  *   * * *   * :FAST.HOLD       Always     Mixed
:                                  :SLOW.HOLD       Never      None
:               * *  *   * * *   * :*HOLD
:0123456789012345678901234567890123:-----------------------------------
:   **      ** **      ******      :RUN             Sometimes  Clusters
:   **      ** *       **** *      :NO_TAIL         Often      Clusters
:    *      *  *       ** *        :QUICK_DN        Sometimes  Runs
:   **      ** **      * ****      :QUICK_UP        Often      Clusters
:   **      ** *       * ** *      :*RUN
:0123456789012345678901234567890123:-----------------------------------
:                 **               :ALT  Infrequent Clusters   Minor   (good)
:**     ****     * ** *       *** *:P/R  Sometimes  Clusters   Notable
:               * *  *     * *   * :HLD  Infrequent Runs       Minor
:   **      ** **      ******      :RUN  Sometimes  Clusters   Notable (good)
:  *  **      *                    :UNCLAIMED
```

Batch 8

```
:01234567890123456789012345678:-----------------------------------
: * ********** *** * ** ******:UP
:* *        * *   * *  *      :DN
: **        ***   ***  *      :ALT?
:****      ***** ****** *     :ADD
:****      ***** ********     :ALT1
:****      ***** *****        :ALT            Sometimes  Clusters
:****      * *** *****        :UNAMBIGUOUS    Often      Clusters
: ***                         :OPTIMAL.ALT    Infrequent Clusters
: ***      * **   ** *        :SIMPLE.ALT     Sometimes  Runs
:  *       ** *  ****         :FAST.ALT       Sometimes  Clusters
:** *        * *     *        :SLOW.ALT       Sometimes  Runs
:****      * *** *****        :*ALT
:01234567890123456789012345678:-----------------------------------
: * ********** *** * ** *** **:RELEASE        Often      Runs
: * ****** *** *** * ** * * **:ENDS_UP        Often      Mixed
: * ****** * *  *  * ** * * **:SIMPLE.P/R     Often      Mixed
: * **** * * *       ** * * * :PAUSED         Sometimes  Runs
: * **** *            *   *   :OPTIMAL.P/R    Sometimes  Runs
: * **** * * * *      * * *   :FEW.P/R        Sometimes  Mixed
:     *******    * *  * *** **:FAST.P/R       Often      Runs
: * **       * **    *        :SLOW.P/R       Sometimes  Runs
: * ********** *** * ** *** **:*P/R
:01234567890123456789012345678:-----------------------------------
:* *        *     * *         :HOLD           Infrequent Runs
:* *              * *         :ENDS_DN        Often      Runs
:  *              *           :SIMPLE.HOLD    Sometimes  Runs
:  *                          :PAUSED.DN      Sometimes  Isolated
:  *                          :OPTIMAL.HOLD   Sometimes  Isolated
:* *                          :FEW.HOLD       Sometimes  Runs
:  *        *     * *         :FAST.HOLD      Often      Runs
:*                            :SLOW.HOLD      Sometimes  Isolated
:* *        *     * *         :*HOLD
:01234567890123456789012345678:-----------------------------------
:       *   * * **** * * *  **:RUN            Sometimes  Runs
:                        *    :NO_TAIL        Infrequent Isolated
:       *       ** * *   *  **:QUICK_DN       Sometimes  Runs
:             *   *    *      :QUICK_UP       Sometimes  Runs
:       *   * * **** * * *  **:*RUN
:01234567890123456789012345678:-----------------------------------
: ***        **   **          :ALT  Infrequent Clusters   Minor   (good)
: * ********** *** * ** * * **:P/R  Often      Mixed      Major
:* *        *     * *         :HLD  Infrequent Runs       Minor
:       *   * * ****   * *   *:RUN  Sometimes  Runs       Notable (poor)
:                          *  :UNCLAIMED
```

Batch 9

```
:012345678:-----------------------------------
:******* *:UP
:      **  :DN
:       *  :ALT?
:      * *:ADD
:      ***:ALT1
:          :ALT
:          :UNAMBIGUOUS
:          :OPTIMAL.ALT
:          :SIMPLE.ALT
:          :FAST.ALT
:          :SLOW.ALT
:          :*ALT
:012345678:-----------------------------------
:******* *:RELEASE         Often      Block
:******* *:ENDS_UP         Always     Block
:******* *:SIMPLE.P/R      Always     Block
:******* *:PAUSED          Always     Block
:**** **  :OPTIMAL.P/R     Often      Runs
:******* *:FEW.P/R         Always     Block
:     *    :FAST.P/R        Infrequent Isolated
:***** * *:SLOW.P/R        Often      Runs
:******* *:*P/R
:012345678:-----------------------------------
:      **  :HOLD            Sometimes  Runs
:          :ENDS_DN         Never      None
:      *   :SIMPLE.HOLD     Sometimes  Isolated
:      *   :PAUSED.DN       Sometimes  Isolated
:      *   :OPTIMAL.HOLD    Sometimes  Isolated
:      **  :FEW.HOLD        Always     Runs
:       *  :FAST.HOLD       Sometimes  Isolated
:      *   :SLOW.HOLD       Sometimes  Isolated
:      **  :*HOLD
:012345678:-----------------------------------
:          :RUN
:          :NO_TAIL
:          :QUICK_DN
:          :QUICK_UP
:          :*RUN
:012345678:-----------------------------------
:          :ALT  Never      None       Absent
:******* *:P/R  Often      Block      Major   (good)
:       *  :HLD  Infrequent Isolated   Notable (poor)
:          :RUN  Never      None       Absent
:          :UNCLAIMED
```

Batch 1Ø

```
:Ø123456789Ø123456789Ø123456:-----------------------------------
:** **   ***    **   ****  *:UP
:  *   *    *  *  *       * :DN
:  *                        :ALT?
: * *                       :ADD
: ***                       :ALT1
:                           :ALT
:                           :UNAMBIGUOUS
:                           :OPTIMAL.ALT
:                           :SIMPLE.ALT
:                           :FAST.ALT
:                           :SLOW.ALT
:                           :*ALT
:Ø123456789Ø123456789Ø123456:-----------------------------------
:** *    ***          ***  *:RELEASE         Sometimes  Clusters
:** *    ***          ***  *:ENDS_UP         Always     Clusters
: * *    ***          ***  *:SIMPLE.P/R      Often      Runs
:   *     **            *  *:PAUSED          Sometimes  Runs
:   *     *                *:OPTIMAL.P/R     Sometimes  Runs
:*  *     **            *  *:FEW.P/R         Sometimes  Runs
:   *    *             **   :FAST.P/R        Sometimes  Runs
:**       **          *    *:SLOW.P/R        Sometimes  Clusters
:** *    ***          ***  *:*P/R
:Ø123456789Ø123456789Ø123456:-----------------------------------
:  *   *    *  *  *       * :HOLD            Infrequent Runs
:  *        *     *       * :ENDS_DN         Sometimes  Runs
:  *        *     *       * :SIMPLE.HOLD     Sometimes  Runs
:  *                        :PAUSED.DN       Sometimes  Isolated
:                           :OPTIMAL.HOLD    Never      None
:                           :FEW.HOLD        Never      None
:  *   *       *  *       * :FAST.HOLD       Often      Runs
:           *               :SLOW.HOLD       Sometimes  Isolated
:  *   *    *  *  *       * :*HOLD
:Ø123456789Ø123456789Ø123456:-----------------------------------
: *  *****  ****** ***** ** :RUN             Often      Runs
:     ***    ***   **    *  :NO_TAIL         Sometimes  Clusters
: *  *  **   ** ** ***** *  :QUICK_DN        Often      Runs
:      *    ****   * *   ** :QUICK_UP        Sometimes  Runs
: *  *  **   ** ** ***** *  :*RUN
:Ø123456789Ø123456789Ø123456:-----------------------------------
:                           :ALT  Never      None       Absent
:** *    ***          ***  *:P/R  Sometimes  Clusters   Notable
:  *        *     *       * :HLD  Infrequent Runs       Minor
: *  *****  ****** ***** ** :RUN  Often      Runs       Major
:                           :UNCLAIMED
```

Batch 11

```
:Ø123456789Ø12345678:-----------------------------------
:*** ***** *********:UP
:* **    **         :DN
: * *     *         :ALT?
:* * *   * *        :ADD
:*****   ***        :ALT1
:                   :ALT
:                   :UNAMBIGUOUS
:                   :OPTIMAL.ALT
:                   :SIMPLE.ALT
:                   :FAST.ALT
:                   :SLOW.ALT
:                   :*ALT
:Ø123456789Ø12345678:-----------------------------------
:*** ***** *********:RELEASE         Often      Runs
: ** *****   *******:ENDS_UP         Often      Runs
: ** *****   *******:SIMPLE.P/R      Often      Runs
: ** *****   *******:PAUSED          Often      Runs
: ** ***** * *******:OPTIMAL.P/R     Often      Runs
: ** ***** *********:FEW.P/R         Often      Runs
:*   **    ** *   * :FAST.P/R        Sometimes  Runs
: **   ***   * *** *:SLOW.P/R        Sometimes  Runs
: ** *****   *******:*P/R
:Ø123456789Ø12345678:-----------------------------------
:* **    **         :HOLD            Infrequent Runs
:*  *     *         :ENDS_DN         Sometimes  Runs
:  **    **         :SIMPLE.HOLD     Often      Runs
:  **    **         :PAUSED.DN       Often      Runs
:  **    **         :OPTIMAL.HOLD    Often      Runs
:  **    **         :FEW.HOLD        Often      Runs
:*  *     *         :FAST.HOLD       Sometimes  Runs
:  *     *          :SLOW.HOLD       Sometimes  Runs
:* **    **         :*HOLD
:Ø123456789Ø12345678:-----------------------------------
:                   :RUN
:                   :NO_TAIL
:                   :QUICK_DN
:                   :QUICK_UP
:                   :*RUN
:Ø123456789Ø12345678:-----------------------------------
:                   :ALT  Never      None       Absent
:*** ***** *********:P/R  Often      Runs       Major    (good)
:*  *     *         :HLD  Infrequent Runs       Minor
:                   :RUN  Never      None       Absent
:                   :UNCLAIMED
```

```
    Batch 12
:012345678901234567890123456:-------------------------------------
:***************************:UP
:                           :DN
:                           :ALT?
:                           :ADD
:                           :ALT1
:                           :ALT
:                           :UNAMBIGUOUS
:                           :OPTIMAL.ALT
:                           :SIMPLE.ALT
:                           :FAST.ALT
:                           :SLOW.ALT
:                           :*ALT
:012345678901234567890123456:-------------------------------------
:********************** * **:RELEASE         Often      Runs
:***************** **** * **:ENDS_UP         Often      Runs
:*****************  *** * **:SIMPLE.P/R      Often      Runs
:****************   *** *  *:PAUSED          Often      Clusters
:** **  * **  **     ** *   :OPTIMAL.P/R     Sometimes  Runs
:***** ** *** ****   ** *   :FEW.P/R         Often      Runs
:    * * **************   **:FAST.P/R        Often      Clusters
:**** * *               *   :SLOW.P/R        Infrequent Clusters
:****************   *** *  *:*P/R
:012345678901234567890123456:-------------------------------------
:                           :HOLD
:                           :ENDS_DN
:                           :SIMPLE.HOLD
:                           :PAUSED.DN
:                           :OPTIMAL.HOLD
:                           :FEW.HOLD
:                           :FAST.HOLD
:                           :SLOW.HOLD
:                           :*HOLD
:012345678901234567890123456:-------------------------------------
:     *  *   *    ***  * ***:RUN             Sometimes  Runs
:                 *         :NO_TAIL         Infrequent Isolated
:     *  *   *    ***  * ***:QUICK_DN        Always     Runs
:                           :QUICK_UP        Never      None
:     *  *   *    ***  * ***:*RUN
:012345678901234567890123456:-------------------------------------
:                           :ALT  Never      None       Absent
:***************** **** * **:P/R  Often      Runs       Major   (good)
:                           :HLD  Never      None       Absent
:                 **   * ** :RUN  Infrequent Runs       Notable
:                           :UNCLAIMED
```

APPENDIX FIVE

FEATURE BY STRATEGY TABLES FROM CASE STUDY ONE

APPENDIX 47

Batch 1

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major
 Major features    :Ends up Simple Few
 Notable features :Paused Optimal Fast Slow
 Minor features    :Presses
 Absent features   :none
HOLDING STRATEGY Minor
 Major features    :none
 Notable features :Simple Paused Optimal Fast Slow
 Minor features    :none
 Absent features   :none
RUNNING STRATEGY Minor    (poor)
 Major features    :none
 Notable features :Quick dn Quick up
 Minor features    :none
 Absent features   :No tail
```

Batch 2

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Notable
 Major features    :Ends up Simple Few
 Notable features :Paused Optimal Fast Slow
 Minor features    :none
 Absent features   :Presses
HOLDING STRATEGY Minor
 Major features    :none
 Notable features :Ends dn Simple Paused Optimal Few Fast Slow
 Minor features    :none
 Absent features   :none
RUNNING STRATEGY Minor
 Major features    :Quick dn
 Notable features :No tail Quick up
 Minor features    :none
 Absent features   :none
```

Batch 3

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major   (good)
 Major features    :Simple Paused Optimal Few
 Notable features  :Fast Slow
 Minor features    :none
 Absent features   :Presses
HOLDING STRATEGY Minor   (good)
 Major features    :none
 Notable features  :Ends dn Simple Paused Optimal Few Fast Slow
 Minor features    :none
 Absent features   :none
RUNNING STRATEGY Minor
 Major features    :none
 Notable features  :No tail Quick dn Quick up
 Minor features    :none
 Absent features   :none
```

Batch 4

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major   (good)
 Major features    :Ends up Simple Paused Slow
 Notable features  :Optimal Few
 Minor features    :Fast
 Absent features   :Presses
HOLDING STRATEGY Absent
RUNNING STRATEGY Notable (poor)
 Major features    :Quick dn
 Notable features  :none
 Minor features    :none
 Absent features   :No tail Quick up
```

Batch 5

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Minor   (good)
 Major features    :Unambiguous Optimal Simple
 Notable features :Fast Slow
 Minor features    :none
 Absent features   :none
PRESS/RELEASE STRATEGY Major
 Major features    :Ends up Simple Optimal Few
 Notable features :Paused Fast Slow
 Minor features    :none
 Absent features   :Presses
HOLDING STRATEGY Notable
 Major features    :Optimal Few Fast
 Notable features :Ends dn Simple Paused Slow
 Minor features    :none
 Absent features   :none
RUNNING STRATEGY Minor    (poor)
 Major features    :none
 Notable features :Quick dn
 Minor features    :none
 Absent features   :No tail Quick up
```

Batch 6

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Minor   (good)
 Major features    :Simple
 Notable features :Optimal Fast Slow
 Minor features    :none
 Absent features   :none
PRESS/RELEASE STRATEGY Major   (good)
 Major features    :Ends up Simple Paused Optimal Few
 Notable features :Fast Slow
 Minor features    :none
 Absent features   :Presses
HOLDING STRATEGY Minor
 Major features    :none
 Notable features :Ends dn Simple Paused Optimal Fast Slow
 Minor features    :none
 Absent features   :none
RUNNING STRATEGY Minor
 Major features    :none
 Notable features :No tail
 Minor features    :none
 Absent features   :Quick up
```

Batch 7

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Minor   (good)
 Major features    :none
 Notable features :Optimal Simple
 Minor features    :none
 Absent features   :Slow
PRESS/RELEASE STRATEGY Notable
 Major features    :Ends up Simple Few Fast
 Notable features :Paused Optimal
 Minor features    :Slow
 Absent features   :Presses
HOLDING STRATEGY Minor
 Major features    :none
 Notable features :Ends dn Simple Paused Optimal Few
 Minor features    :none
 Absent features   :Slow
RUNNING STRATEGY Notable (good)
 Major features    :No tail Quick up
 Notable features :Quick dn
 Minor features    :none
 Absent features   :none
```

Batch 8

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY (good)
 Major features    :Unambiguous
 Notable features :Simple Fast Slow
 Minor features    :Optimal
 Absent features   :none
PRESS/RELEASE STRATEGY
 Major features    :Ends up Simple Fast
 Notable features :Paused Optimal Few Slow
 Minor features    :Presses
 Absent features   :none
HOLDING STRATEGY
 Major features    :Ends dn Fast
 Notable features :Simple Paused Optimal Few Slow
 Minor features    :none
 Absent features   :none
RUNNING STRATEGY (poor)
 Major features    :none
 Notable features :Quick dn Quick up
 Minor features    :No tail
 Absent features   :none
```

```
Batch 9

**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major   (good)
 Major features   :Ends up Simple Paused Optimal Few Slow
 Notable features :none
 Minor features   :Fast
 Absent features  :Presses
HOLDING STRATEGY Notable (poor)
 Major features   :none
 Notable features :Simple Paused Optimal Fast Slow
 Minor features   :none
 Absent features  :Ends dn
RUNNING STRATEGY Absent
```

```
Batch 10
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Notable
 Major features   :Simple
 Notable features :Paused Optimal Few Fast Slow
 Minor features   :none
 Absent features  :Presses
HOLDING STRATEGY Minor
 Major features   :Fast
 Notable features :Ends dn Simple Paused Slow
 Minor features   :none
 Absent features  :Optimal Few
RUNNING STRATEGY Major
 Major features   :Quick dn
 Notable features :No tail Quick up
 Minor features   :none
 Absent features  :none
SUB-GROUP
012345678901234567890123456
 *  *****  ****** ***** ** :MAJOR GROUP
     ***    ***   **    *  :NO_TAIL
```

Batch 11

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major   (good)
 Major features    :Ends up Simple Paused Optimal Few
 Notable features :Fast Slow
 Minor features    :none
 Absent features  :Presses
HOLDING STRATEGY Minor
 Major features    :Simple Paused Optimal Few
 Notable features :Ends dn Fast Slow
 Minor features    :none
 Absent features  :none
RUNNING STRATEGY Absent
```

Batch 12

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major   (good)
 Major features    :Ends up Simple Paused Few Fast
 Notable features :Optimal
 Minor features    :Slow
 Absent features  :Presses
HOLDING STRATEGY Absent
RUNNING STRATEGY Notable
 Major features    :none
 Notable features :none
 Minor features    :No tail
 Absent features  :Quick up
```

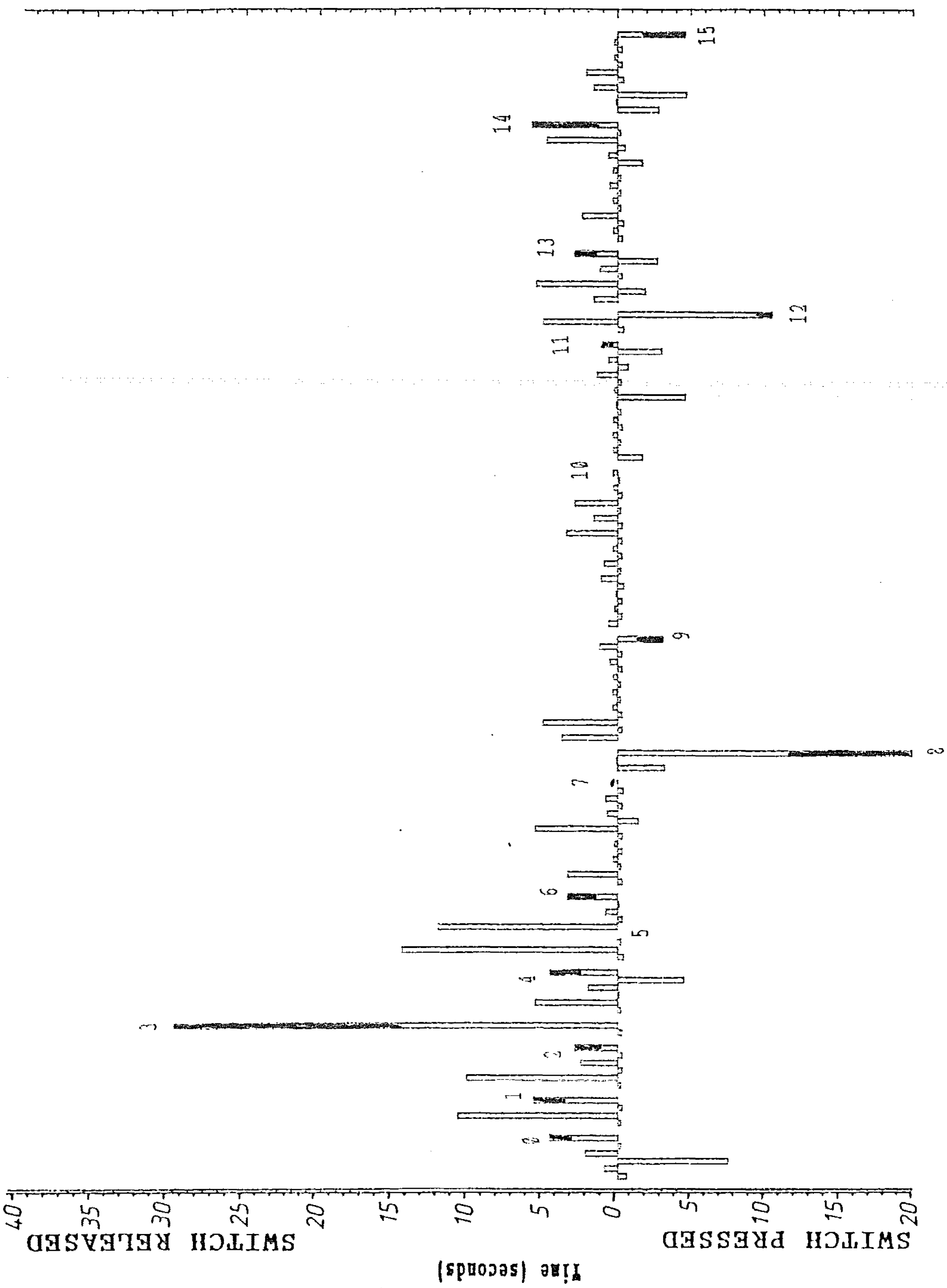
APPENDIX 53

APPENDIX SIX

SELECT BATCHES FROM CASE STUDY TWO

APPENDIX 54

Batch 3



APPENDIX 55

Batch 3

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major   (poor)
 Major features    :Fast
 Notable features :Ends up Few Presses
 Minor features    :Simple Paused Optimal Slow
 Absent features   :none
HOLDING STRATEGY Notable (poor)
 Major features    :Fast
 Notable features :Ends dn Few Slow
 Minor features    :none
 Absent features   :Simple Paused Optimal
RUNNING STRATEGY Minor
 Major features    :none
 Notable features :No tail Quick dn Quick up
 Minor features    :none
 Absent features   :none
```

APPENDIX 56

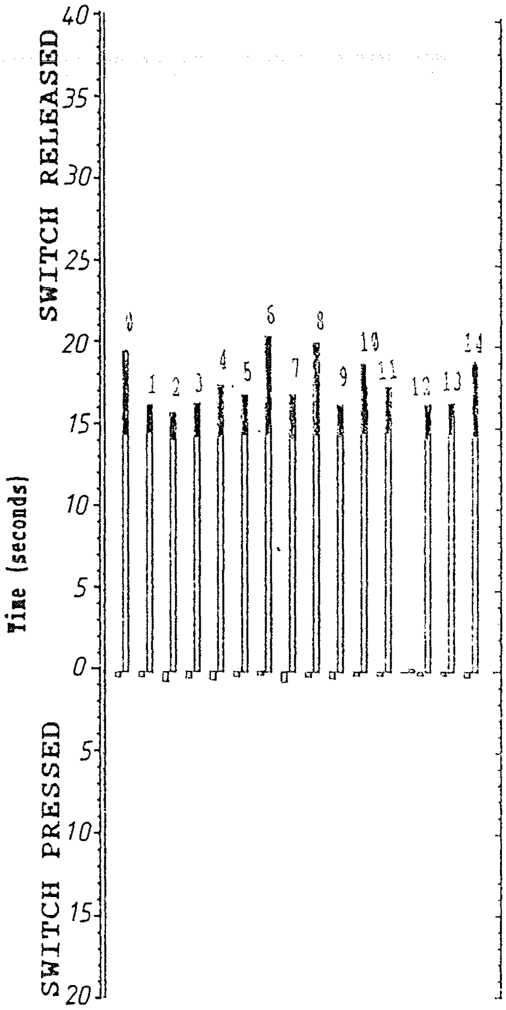
Batch 3

```
:0123456789012345:-----------------------------------
:******** ** *** :UP
:*   *   ** **  *:DN
:    *   * **    :ALT?
:   * * * ****   :ADD
:   *** ******   :ALT1
:          ***   :ALT             Infrequent Clusters
:          **    :UNAMBIGUOUS     Sometimes  Runs
:                :OPTIMAL.ALT     Never      None
:                :SIMPLE.ALT      Never      None
:          ***   :FAST.ALT        Always     Clusters
:                :SLOW.ALT        Never      None
:          ***   :*ALT
:0123456789012345:-----------------------------------
:******** ** *** :RELEASE         Often      Runs
:** ** *       * :ENDS_UP         Sometimes  Runs
:   *            :SIMPLE.P/R      Infrequent Isolated
:   *            :PAUSED          Infrequent Isolated
:   *            :OPTIMAL.P/R     Infrequent Isolated
: * * *      *   :FEW.P/R         Sometimes  Runs
:*** **** ** *** :FAST.P/R        Often      Runs
:   *            :SLOW.P/R        Infrequent Isolated
: *    **      * :PRESSES         Sometimes  Runs
:******** ** *** :*P/R
:0123456789012345:-----------------------------------
:*   *   ** **  *:HOLD            Sometimes  Runs
:        **  *  *:ENDS_DN         Sometimes  Runs
:                :SIMPLE.HOLD     Never      None
:                :PAUSED.DN       Never      None
:                :OPTIMAL.HOLD    Never      None
:        *   *   :FEW.HOLD        Sometimes  Runs
:*   *    * **  *:FAST.HOLD       Often      Runs
:        *       :SLOW.HOLD       Sometimes  Isolated
:*   *   ** **  *:*HOLD
:0123456789012345:-----------------------------------
:          **  * :RUN             Infrequent Runs
:          **    :NO_TAIL         Sometimes  Runs
:          *   * :QUICK_DN        Sometimes  Runs
:           *    :QUICK_UP        Sometimes  Isolated
:          **  * :*RUN
:0123456789012345:-----------------------------------
:                :ALT  Never      None       Absent
:******** *  *** :P/R  Often      Runs       Major   (poor)
:*   *   **  *  *:HLD  Sometimes  Runs       Notable (poor)
:          **  * :RUN  Infrequent Runs       Minor
:                :UNCLAIMED
```

APPENDIX 57

Batch 6

STRATEGY FEATURES
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major (good)
 Major features :Ends up Simple Paused Optimal Few Fast
 Notable features :none
 Minor features :Slow
 Absent features :Presses
HOLDING STRATEGY Absent
RUNNING STRATEGY Absent



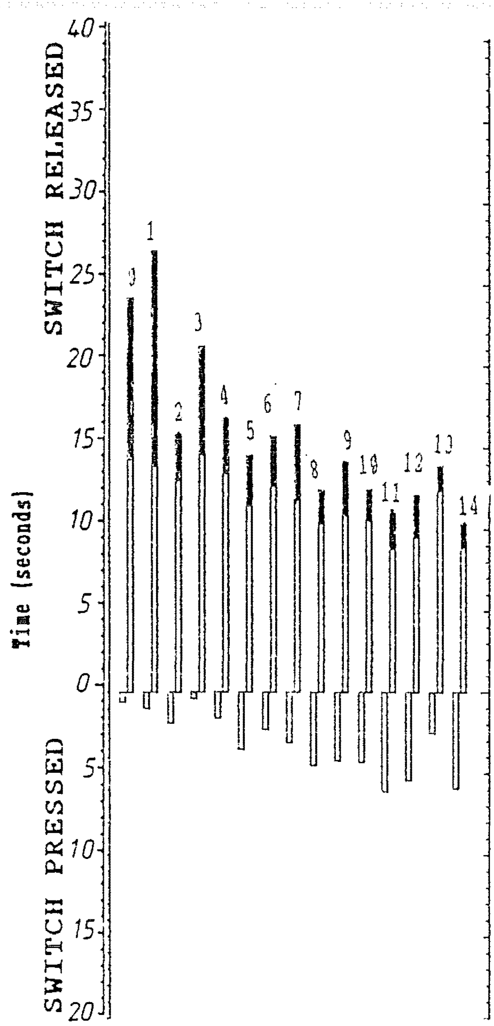
Batch 6

```
:Ø12345678901234:------------------------------------
:***************:UP
:               :DN
:               :ALT?
:               :ADD
:               :ALT1
:               :ALT
:               :UNAMBIGUOUS
:               :OPTIMAL.ALT
:               :SIMPLE.ALT
:               :FAST.ALT
:               :SLOW.ALT
:               :*ALT
:Ø12345678901234:------------------------------------
:***************:RELEASE         Always     Block
:***************:ENDS_UP         Always     Block
:***************:SIMPLE.P/R      Always     Block
:***************:PAUSED          Always     Block
:************ **:OPTIMAL.P/R     Often      Block
:***************:FEW.P/R         Always     Block
: ***** * ******:FAST.P/R        Often      Runs
:*     * *      :SLOW.P/R        Infrequent Runs
:               :PRESSES         Never      None
:***************:*P/R
:Ø12345678901234:------------------------------------
:               :HOLD
:               :ENDS_DN
:               :SIMPLE.HOLD
:               :PAUSED.DN
:               :OPTIMAL.HOLD
:               :FEW.HOLD
:               :FAST.HOLD
:               :SLOW.HOLD
:               :*HOLD
:Ø12345678901234:------------------------------------
:               :RUN
:               :NO_TAIL
:               :QUICK_DN
:               :QUICK_UP
:               :*RUN
:Ø12345678901234:------------------------------------
:               :ALT  Never      None       Absent
:***************:P/R  Always     Block      Major    (good)
:               :HLD  Never      None       Absent
:               :RUN  Never      None       Absent
:               :UNCLAIMED
```

APPENDIX 59

Batch 14

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major   (good)
 Major features   :Ends up Simple Paused Optimal Few Fast
 Notable features :none
 Minor features   :Slow
 Absent features  :Presses
HOLDING STRATEGY Notable
 Major features   :none
 Notable features :none
 Minor features   :none
 Absent features  :Ends dn Slow
RUNNING STRATEGY Absent
```



APPENDIX 6Ø

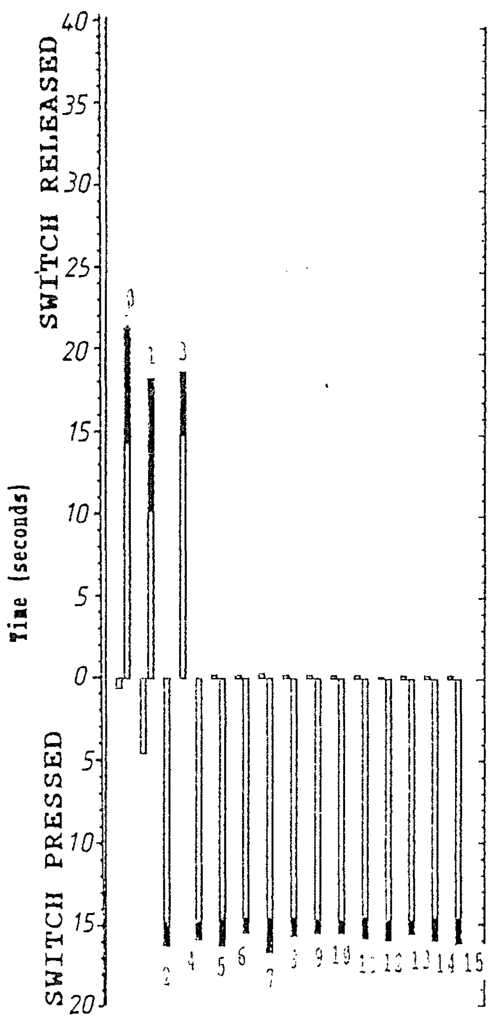
Batch 14

```
:Ø123456789Ø1234:---------------------------------------
:***************:UP
:     * ****** *:DN
:     ********* :ALT?
:    ***********:ADD
:    ***********:ALT1
:    ***********:ALT              Often      Clusters
:    * *      * :UNAMBIGUOUS      Sometimes  Runs
:    ***********:OPTIMAL.ALT      Always     Clusters
:    ***********:SIMPLE.ALT       Always     Clusters
:    ***********:FAST.ALT         Always     Clusters
:               :SLOW.ALT         Never      None
:    ***********:*ALT
:Ø123456789Ø1234:---------------------------------------
:***************:RELEASE          Always     Block
:***************:ENDS_UP          Always     Block
:***************:SIMPLE.P/R       Always     Block
:***************:PAUSED           Always     Block
:***************:OPTIMAL.P/R      Always     Block
:***************:FEW.P/R          Always     Block
:  * ***********:FAST.P/R         Often      Runs
:** *           :SLOW.P/R         Infrequent Runs
:               :PRESSES          Never      None
:***************:*P/R
:Ø123456789Ø1234:---------------------------------------
:     * ****** *:HOLD             Sometimes  Runs
:               :ENDS_DN          Never      None
:     * ****** *:SIMPLE.HOLD      Always     Runs
:     * ****** *:PAUSED.DN        Always     Runs
:     * ****** *:OPTIMAL.HOLD     Always     Runs
:     * ****** *:FEW.HOLD         Always     Runs
:     * ****** *:FAST.HOLD        Always     Runs
:               :SLOW.HOLD        Never      None
:     * ****** *:*HOLD
:Ø123456789Ø1234:---------------------------------------
:               :RUN
:               :NO_TAIL
:               :QUICK_DN
:               :QUICK_UP
:               :*RUN
:Ø123456789Ø1234:---------------------------------------
:               :ALT  Never       None       Absent
:***************:P/R  Always      Block      Major    (good)
:               :HLD  Never       None       Notable
:               :RUN  Never       None       Absent
:               :UNCLAIMED
```

APPENDIX 61

Batch 19

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Minor   (good)
 Major features    :none
 Notable features :Unambiguous Fast Slow
 Minor features    :none
 Absent features   :none
PRESS/RELEASE STRATEGY Minor   (good)
 Major features    :none
 Notable features :Fast Slow
 Minor features    :none
 Absent features   :Presses
HOLDING STRATEGY Major   (good)
 Major features    :Ends dn Fast
 Notable features :none
 Minor features    :Slow
 Absent features   :none
RUNNING STRATEGY Absent
```



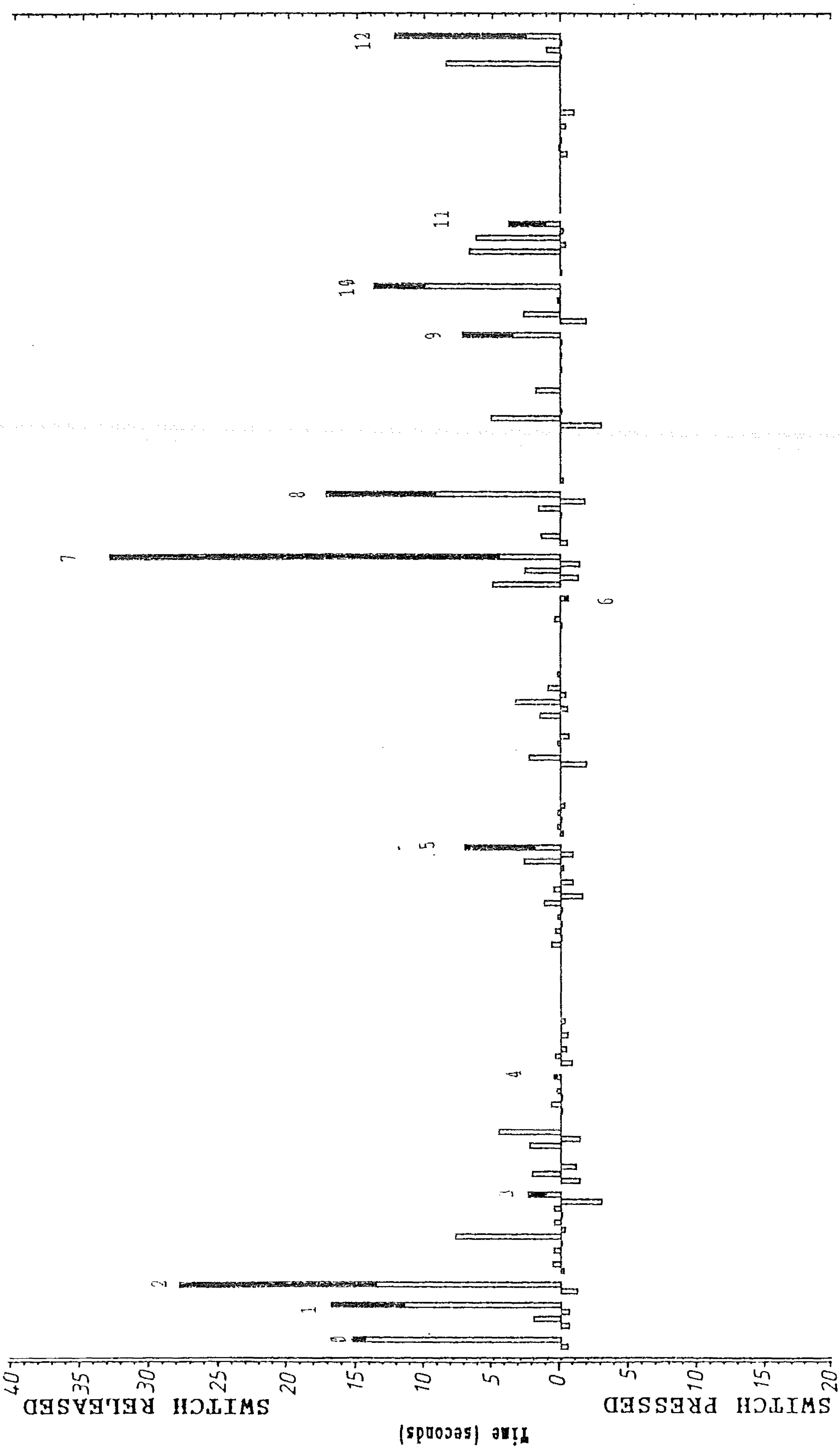
APPENDIX 62

Batch 19

```
:Ø123456789Ø12345:-----------------------------------
:** *            :UP
: ** ************:DN
:  **            :ALT?
: ****           :ADD
: ****           :ALT1
: ****           :ALT               Infrequent Clusters
:  ***           :UNAMBIGUOUS       Sometimes  Clusters
: ****           :OPTIMAL.ALT       Always     Clusters
: ****           :SIMPLE.ALT        Always     Clusters
:  ***           :FAST.ALT          Sometimes  Clusters
: *              :SLOW.ALT          Sometimes  Isolated
: ****           :*ALT
:Ø123456789Ø12345:-----------------------------------
:** *            :RELEASE           Infrequent Runs
:** *            :ENDS_UP           Always     Runs
:** *            :SIMPLE.P/R        Always     Runs
:** *            :PAUSED            Always     Runs
:** *            :OPTIMAL.P/R       Always     Runs
:** *            :FEW.P/R           Always     Runs
:   *            :FAST.P/R          Sometimes  Isolated
:**              :SLOW.P/R          Sometimes  Clusters
:                :PRESSES           Never      None
:** *            :*P/R
:Ø123456789Ø12345:-----------------------------------
: ** ************:HOLD              Often      Runs
:  * ************:ENDS_DN           Often      Runs
: ** ************:SIMPLE.HOLD       Always     Runs
: ** ************:PAUSED.DN         Always     Runs
: ** ************:OPTIMAL.HOLD      Always     Runs
: ** ************:FEW.HOLD          Always     Runs
:  * ************:FAST.HOLD         Often      Runs
: *              :SLOW.HOLD         Infrequent Isolated
: ** ************:*HOLD
:Ø123456789Ø12345:-----------------------------------
:                :RUN
:                :NO_TAIL
:                :QUICK_DN
:                :QUICK_UP
:                :*RUN
:Ø123456789Ø12345:-----------------------------------
:  ***           :ALT  Infrequent Clusters   Minor    (good)
:** *            :P/R  Infrequent Runs       Minor    (good)
:  * ************:HLD  Often      Runs       Major    (good)
:                :RUN  Never      None       Absent
:                :UNCLAIMED
```

APPENDIX 63

Batch 24



APPENDIX 64

Batch 24

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major    (poor)
 Major features    :Ends up
 Notable features :Fast Slow
 Minor features    :Simple Paused Optimal Few Presses
 Absent features   :none
HOLDING STRATEGY Minor    (poor)
 Major features    :none
 Notable features :none
 Minor features    :none
 Absent features   :Ends dn Simple Paused Optimal Few Slow
RUNNING STRATEGY Notable
 Major features    :Quick dn
 Notable features :No tail
 Minor features    :none
 Absent features   :Quick up
```

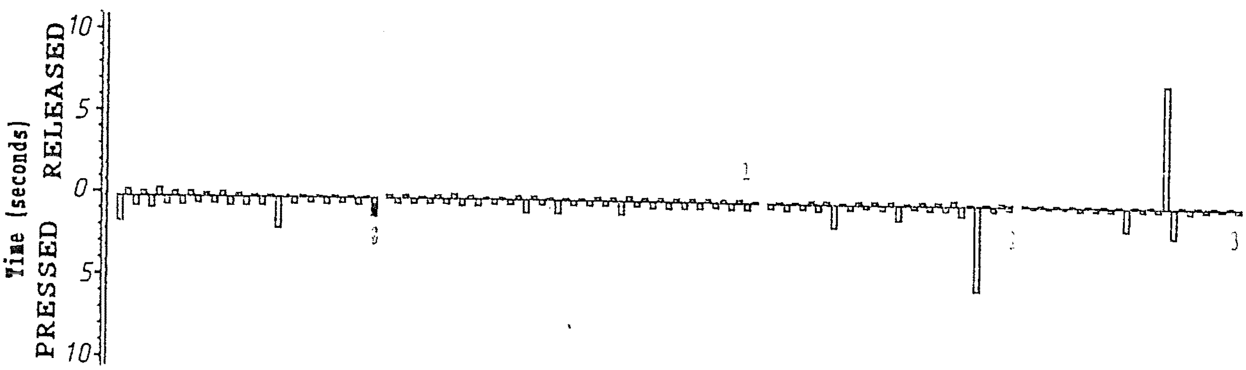
Batch 24

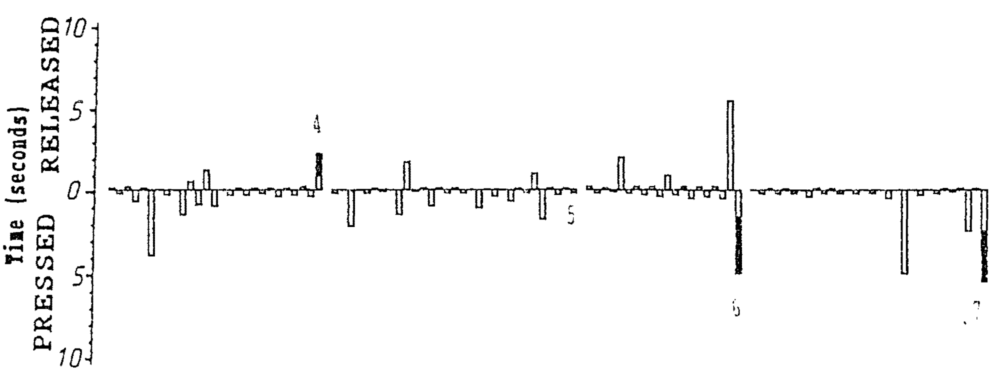
```
:0123456789012:-----------------------------------
:*************:UP
:   *     *   :DN
:   *     *   :ALT?
:  * *   * *  :ADD
:  ***   ***  :ALT1
:             :ALT
:             :UNAMBIGUOUS
:             :OPTIMAL.ALT
:             :SIMPLE.ALT
:             :FAST.ALT
:             :SLOW.ALT
:             :*ALT
:0123456789012:-----------------------------------
:*************:RELEASE          Always     Block
:***  * ******:ENDS_UP          Often      Runs
:* *     *    :SIMPLE.P/R       Infrequent Runs
:* *          :PAUSED           Infrequent Runs
:* *          :OPTIMAL.P/R      Infrequent Runs
:***          :FEW.P/R          Infrequent Clusters
:*  ** *  *** :FAST.P/R         Sometimes  Runs
: **  * **   *:SLOW.P/R         Sometimes  Runs
:       *   **:PRESSES          Infrequent Runs
:***  * ******:*P/R
:0123456789012:-----------------------------------
:   *     *   :HOLD             Infrequent Runs
:             :ENDS_DN          Never      None
:             :SIMPLE.HOLD      Never      None
:             :PAUSED.DN        Never      None
:             :OPTIMAL.HOLD     Never      None
:             :FEW.HOLD         Never      None
:   *     *   :FAST.HOLD        Always     Runs
:             :SLOW.HOLD        Never      None
:   *     *   :*HOLD
:0123456789012:-----------------------------------
:    ***  *  *:RUN              Sometimes  Runs
:    * *      :NO_TAIL          Sometimes  Runs
:    ***     *:QUICK_DN         Often      Clusters
:             :QUICK_UP         Never      None
:    ***     *:*RUN
:0123456789012:-----------------------------------
:             :ALT  Never       None       Absent
:**** * ******:P/R  Often       Runs       Major    (poor)
:   *     *   :HLD  Infrequent  Runs       Minor    (poor)
:    ***  *  *:RUN  Sometimes   Runs       Notable
:             :UNCLAIMED
```

APPENDIX 66

Batch 27

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Notable
 Major features    :none
 Notable features :none
 Minor features    :none
 Absent features   :Ends up Simple Paused Optimal Few Slow Presses
HOLDING STRATEGY Notable (poor)
 Major features    :none
 Notable features :Ends dn
 Minor features    :none
 Absent features   :Simple Paused Optimal Few Slow
RUNNING STRATEGY Major   (good)
 Major features    :No tail
 Notable features :Quick dn Quick up
 Minor features    :none
 Absent features   :none
```





APPENDIX 67

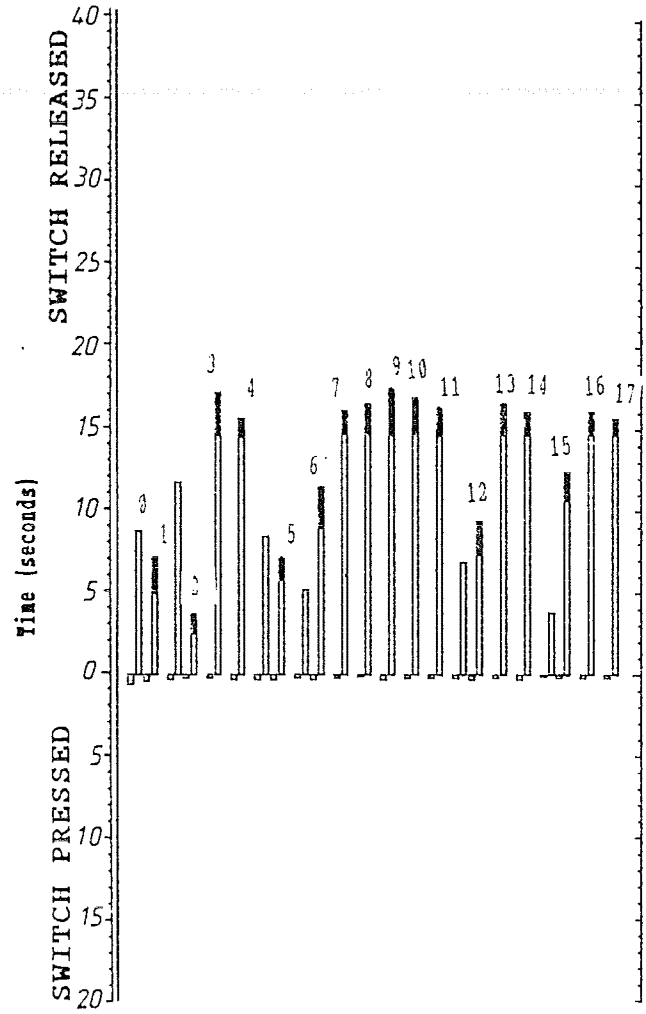
Batch 27

```
:Ø1234567:------------------------------------
:   *  * :UP
:  * * **:DN
:   *    :ALT?
:  * *   :ADD
:  ***   :ALT1
:        :ALT
:        :UNAMBIGUOUS
:        :OPTIMAL.ALT
:        :SIMPLE.ALT
:        :FAST.ALT
:        :SLOW.ALT
:        :*ALT
:Ø1234567:------------------------------------
:   *  * :RELEASE          Sometimes  Runs
:        :ENDS_UP          Never      None
:        :SIMPLE.P/R       Never      None
:        :PAUSED           Never      None
:        :OPTIMAL.P/R      Never      None
:        :FEW.P/R          Never      None
:   *  * :FAST.P/R         Always     Runs
:        :SLOW.P/R         Never      None
:        :PRESSES          Never      None
:   *  * :*P/R
:Ø1234567:------------------------------------
:  * * **:HOLD             Sometimes  Runs
:      **:ENDS_DN          Sometimes  Clusters
:        :SIMPLE.HOLD      Never      None
:        :PAUSED.DN        Never      None
:        :OPTIMAL.HOLD     Never      None
:        :FEW.HOLD         Never      None
:  * * **:FAST.HOLD        Always     Runs
:        :SLOW.HOLD        Never      None
:  * * **:*HOLD
:Ø1234567:------------------------------------
:********:RUN              Always     Block
:******* :NO_TAIL          Often      Block
:** *    :QUICK_DN         Sometimes  Runs
:***  * *:QUICK_UP         Sometimes  Runs
:********:*RUN
:Ø1234567:------------------------------------
:        :ALT  Never      None       Absent
:        :P/R  Never      None       Notable
:       *:HLD  Infrequent Isolated   Notable (poor)
:********:RUN  Always     Block      Major   (good)
:        :UNCLAIMED
```

APPENDIX 68

Batch 29

STRATEGY FEATURES
ALTERNATING STRATEGY Absent
PRESS/RELEASE STRATEGY Major
 Major features :Ends up Few Fast
 Notable features :Simple Paused Optimal Presses
 Minor features :none
 Absent features :Slow
HOLDING STRATEGY Absent
RUNNING STRATEGY Absent



APPENDIX 69

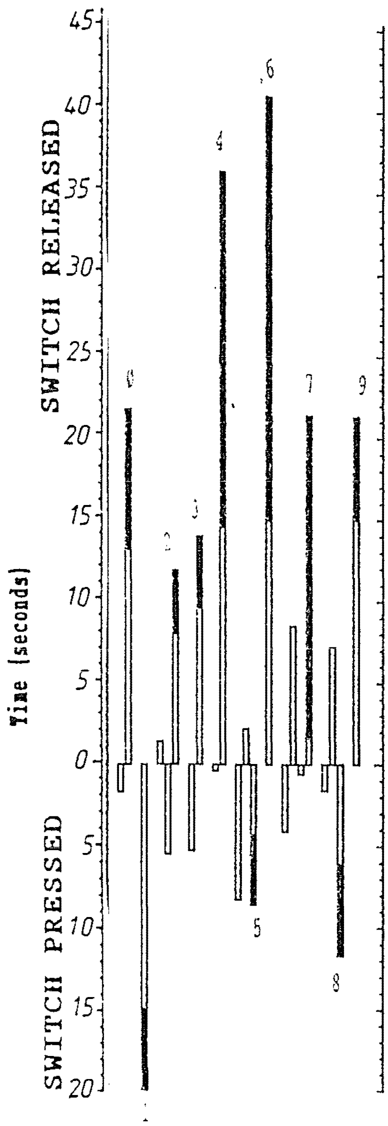
Batch 29

```
:01234567890123456:-----------------------------------
:*****************:UP
:                 :DN
:                 :ALT?
:                 :ADD
:                 :ALT1
:                 :ALT
:                 :UNAMBIGUOUS
:                 :OPTIMAL.ALT
:                 :SIMPLE.ALT
:                 :FAST.ALT
:                 :SLOW.ALT
:                 :*ALT
:01234567890123456:-----------------------------------
:*****************:RELEASE          Always     Block
:*****************:ENDS_UP          Always     Block
:  **  ***** ** **:SIMPLE.P/R       Sometimes  Runs
:  **  ***** ** **:PAUSED           Sometimes  Runs
:  **  ***** ** **:OPTIMAL.P/R      Sometimes  Runs
:*****************:FEW.P/R          Always     Block
:*****************:FAST.P/R         Always     Block
:                 :SLOW.P/R         Never      None
:**  **     *  *  :PRESSES          Sometimes  Runs
:*****************:*P/R
:01234567890123456:-----------------------------------
:                 :HOLD
:                 :ENDS_DN
:                 :SIMPLE.HOLD
:                 :PAUSED.DN
:                 :OPTIMAL.HOLD
:                 :FEW.HOLD
:                 :FAST.HOLD
:                 :SLOW.HOLD
:                 :*HOLD
:01234567890123456:-----------------------------------
:                 :RUN
:                 :NO_TAIL
:                 :QUICK_DN
:                 :QUICK_UP
:                 :*RUN
:01234567890123456:-----------------------------------
:                 :ALT  Never       None       Absent
:*****************:P/R  Always      Block      Major
:                 :HLD  Never       None       Absent
:                 :RUN  Never       None       Absent
:                 :UNCLAIMED
```

APPENDIX 7Ø

Batch 3Ø

```
**STRATEGY FEATURES**
ALTERNATING STRATEGY Notable (good)
 Major features    :none
 Notable features :Unambiguous Optimal Simple Fast Slow
 Minor features    :none
 Absent features   :none
PRESS/RELEASE STRATEGY Major
 Major features    :Ends up Slow
 Notable features :Simple Paused Optimal Fast
 Minor features    :none
 Absent features   :Presses
HOLDING STRATEGY Notable
 Major features    :none
 Notable features :Ends dn Simple Paused Optimal Fast Slow
 Minor features    :none
 Absent features   :none
RUNNING STRATEGY Absent
```



APPENDIX 71

Batch 3Ø

```
:Ø123456789:-----------------------------------
:* *** ****:UP
: *** * ** :DN
: ******** :ALT?
:**********:ADD
:**********:ALT1
:**********:ALT               Always     Block
:**  ***  *:UNAMBIGUOUS       Sometimes  Runs
:** ** *  *:OPTIMAL.ALT       Sometimes  Runs
:** ** *  *:SIMPLE.ALT        Sometimes  Runs
:  ** *    :FAST.ALT          Sometimes  Runs
:**  * ****:SLOW.ALT          Sometimes  Runs
:**********:*ALT
:Ø123456789:-----------------------------------
:* *** ****:RELEASE           Often      Runs
:* *** ** *:ENDS_UP           Often      Runs
:*  ** *  *:SIMPLE.P/R        Sometimes  Runs
:*  ** *  *:PAUSED            Sometimes  Runs
:*  ** *  *:OPTIMAL.P/R       Sometimes  Runs
:* *** ****:FEW.P/R           Always     Runs
:  **      :FAST.P/R          Sometimes  Runs
:*   * ****:SLOW.P/R          Often      Runs
:          :PRESSES           Never      None
:* *** ****:*P/R
:Ø123456789:-----------------------------------
: *** * ** :HOLD              Sometimes  Runs
: *   *  * :ENDS_DN           Sometimes  Runs
: * *      :SIMPLE.HOLD       Sometimes  Runs
: * *      :PAUSED.DN         Sometimes  Runs
: * *      :OPTIMAL.HOLD      Sometimes  Runs
: *** * ** :FEW.HOLD          Always     Runs
:  ** *    :FAST.HOLD         Sometimes  Runs
: *     ** :SLOW.HOLD         Sometimes  Runs
: *** * ** :*HOLD
:Ø123456789:-----------------------------------
:          :RUN
:          :NO_TAIL
:          :QUICK_DN
:          :QUICK_UP
:          :*RUN
:Ø123456789:-----------------------------------
:**        :ALT  Sometimes  Clusters   Notable (good)
:* *** ****:P/R  Often      Runs       Major
: **  * ** :HLD  Sometimes  Runs       Notable
:          :RUN  Never      None       Absent
:          :UNCLAIMED
```